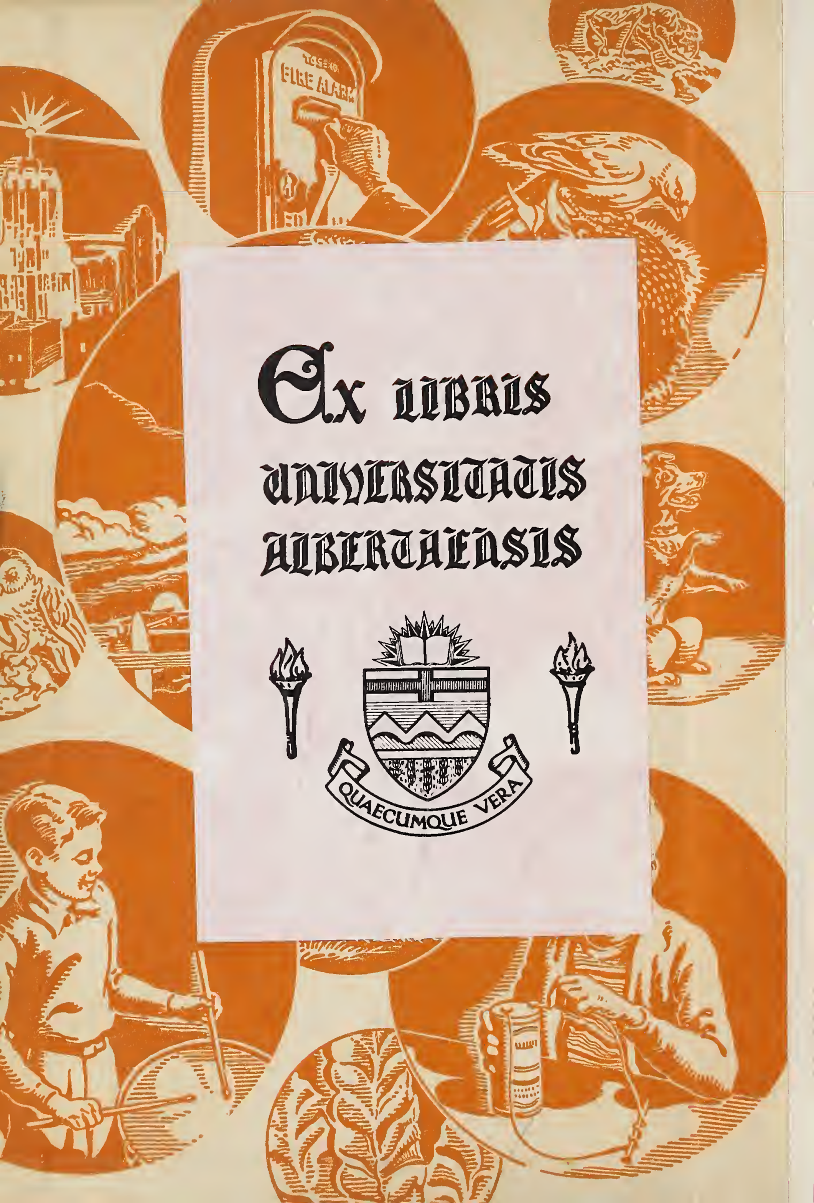
DISCOVERING OUR WORLD

A COURSE IN SCIENCE FOR THE MIDDLE GRADES

BOOK THREE



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Basic Studies in Science

DISCOVERING OUR WORLD

A Course in Science for the
Middle Grades

by
WILBUR L. BEAUCHAMP
MARY MELROSE GLENN O. BLOUGH

• BOOK THREE •

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WHAT KIND OF WORLD ARE YOU MAKING FOR YOURSELF?

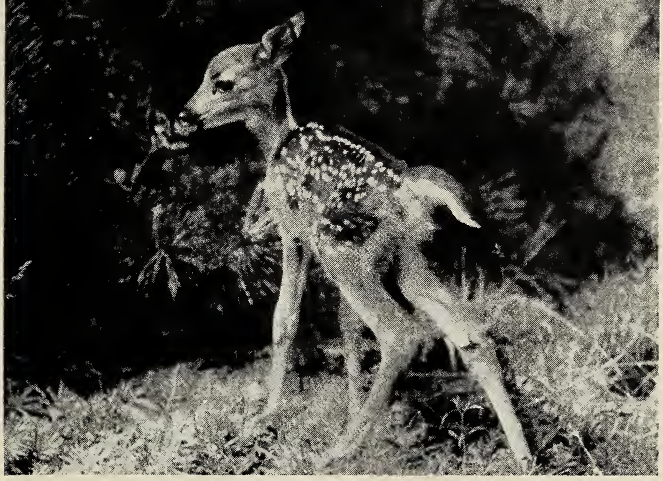
I am one of the three people who wrote this book for you. The other two authors have asked me to write down some things that we all want to say to you before you begin studying the book. I think that the best way to explain what we all want to say is to tell you a little story of something that happened to me one summer when I was camping in the Rocky Mountains of Glacier National Park.

At one of the places where I camped that summer I became acquainted with a very interesting man. At first, I did not know his name or what he did, and he did not know who I was. Before long I decided that he must be a scientist or a science teacher. He seemed to know everything about the mountains, the rivers, the trees, the flowers, and the animals of the northwestern part of our country. He told me just how the mountains were formed, and what different kinds of rocks were in the mountains. He knew about how cold the water was in the high mountain lakes and what kinds of minerals were dissolved in the water.

The plants and the animals of the mountains were all friends of his. He knew what kinds they were, and he knew where they lived and how they lived. He had taken color photographs of over three hundred different kinds of mountain flowers. One day he came back from a long hike very happy because he had been able to take a close-up photograph of a curious little animal called the coney, and he told me all about how the coney gathers hay and puts it away for the winter.

This boy lives in a big city. Yet he finds plenty of opportunities to learn about birds and other animals. How do you think he learns about them?

One day when I told my new friend that I intended to climb up onto one of the glaciers, he explained to me just what to do to keep out of danger on that great mass of ice. He also



Do you know what kind of animal this is? How are the speckles on its coat useful when it is young? How would it act if it were frightened? What laws are there in your state to protect it?

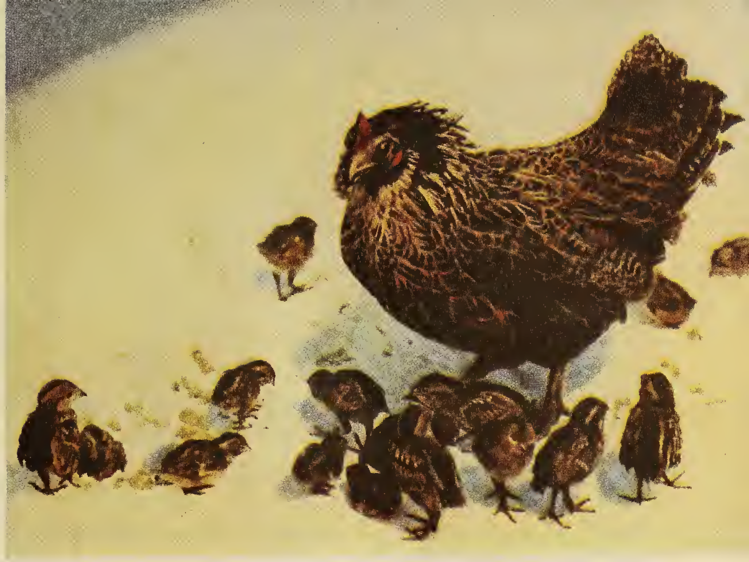
told me where to go and what things to look for so that I would understand what I was seeing and get the most from my trip.

No wonder I thought this man must be a scientist or a science teacher. But when the day came for us to part, imagine my surprise when he told me that he was a captain of policemen in a large western city! "How in the world," I said to myself, "did this man ever have time to learn all these things about the part of the country in which he lives?" He had many important duties in his work of helping protect the people of his city, and he had to be responsible for the work of many other men because

The porcupine is a pet that some sixth-graders had in their schoolroom. They learned what it ate and how it lived, so that they could feed it and make a comfortable home for it.

he was a captain. Yet he was a walking book of knowledge about the out-of-doors.

This man started me thinking, and these are the things I thought: We live in a world of continents, islands, oceans, and seas. But we live in another world, too—a world that each of us makes for himself. It can be a big world or a little world, according to what we make it. My friend the police captain has made a big world for himself. He could have been satisfied with living in the world of a police captain. In that world he would be content with knowing all



These baby quail were taken into a barnyard and put with a mother hen. Suppose they were your pets. What would you feed them? How would you find out how to take care of them?

about the important work of protecting the people in his city and of helping the city to run in an orderly manner.

But my friend was not satisfied to live in such a small world. So he made a bigger world for himself. To the world of his work and his home he has added another world—the world of the rocks and the water, the winds and the rains, the plants and the animals. Because of this bigger world that he has made for himself, he is a happier man. He has found many things to interest him and to thrill him. He is also a

Can you wire an electric bell for your schoolroom door, as these sixth-graders are doing? What makes the bell ring? Why can you hear it ring? To answer these questions, you must know something about two big parts of the world—electricity and sound.

more interesting man to know, and he can easily make worthwhile friends.

What kind of world will you build for yourself? We hope it will be a wide, wide world—a world so full of interesting things that you will never seem to have time enough to do all that you want to do. We hope that this science book will help you discover a larger world in which to live. In the first unit the book will tell you why the plants and the animals that you see act the way they do. It will also help you understand why you act the way you do. The second unit of the book will take you back millions of years and introduce you to a world that no person has ever seen.

We know about this world because scientists have discovered it for us. The third unit of the book will tell you why and how we hear sounds. The fourth unit will open up another part of the world to you. It will tell you many things about that useful servant, electricity. So, each of the ten units in the book will introduce you to a part of the world about which you probably now know very little. Turn to the Table of Contents and see what these units are.

If you read this book carefully, think about what you read, and keep your eyes open to see the things that are happening around you, then, when you have finished the book, you will be able to say, "I have discovered a bigger world than the world I lived in when I began my science study this year."

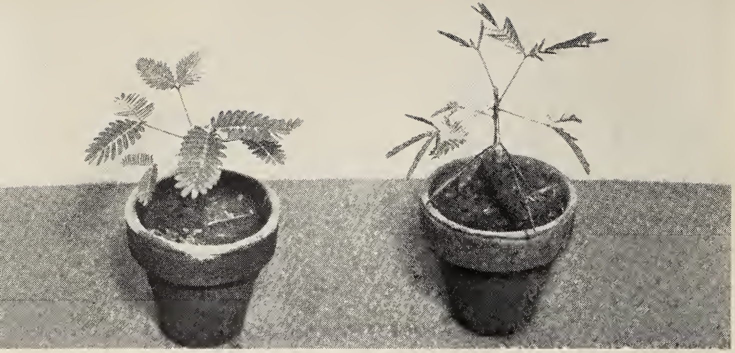
UNIT ONE

HOW DO LIVING THINGS BEHAVE?

IN A TREE near Mary's home a Baltimore oriole was building its deep basket nest, and a robin was building its shallow nest of mud and grass. The nests were almost exactly like the ones in which these birds had been hatched, and they were like the hundreds of other nests that are made every year by Baltimore orioles and robins. The birds had never practiced making nests. Of course they had not watched other birds build nests, and their parents had not taught them how to build nests. Yet the very first nests they made were perfect ones. Have you ever wondered how birds know how to build nests, and why each bird always builds its own kind of nest?

Bob has a pet dog, which he is teaching to do tricks. He has taught the dog to sit up and "beg" for food. In training the dog Bob always gave him dog biscuit or a small piece of meat after he had done the trick well. Circus animals learn to carry umbrellas, roll barrels, and stand on their heads. Do you know how these animals learn to do tricks?

Ruth has a plant that she says can do a trick.



The second plant shows you what happened when Ruth touched it.

When she touches the leaves of the plant, they fold up. One day she held a burning match close to the end of a branch of the plant, and all the leaves folded up. Have you ever seen such a plant?

You may be wondering what these three stories have to do with each other. Well, you know that the Baltimore oriole, the robin, Bob's dog, and Ruth's "trick" plant are all living things. These stories are alike in showing you that every kind of living thing has certain ways of acting. If you watch the dogs, cats, birds, squirrels, and other animals around you, you can find out many strange and interesting things about how they act. You already know something about how these animals find food, eat, grow, and protect themselves, but can you tell why they act the way they do? Let us find out more about how animals act, how plants act, and even how and why you yourself act the way you do.

These puppies are behaving in a way that shows they are thirsty.

What is behavior?

If someone told you to watch your pet dog or cat to find out how it behaves, what would you do? You might not understand what you were supposed to watch for. Probably your mother and your father have often said to you, "Behave yourself!" Perhaps you have told your pet dog to behave himself. What did you mean when you said that? To you, the word "behave" probably means doing the right thing, or doing what you have been told to do. Let us see what *behavior* means to a scientist.

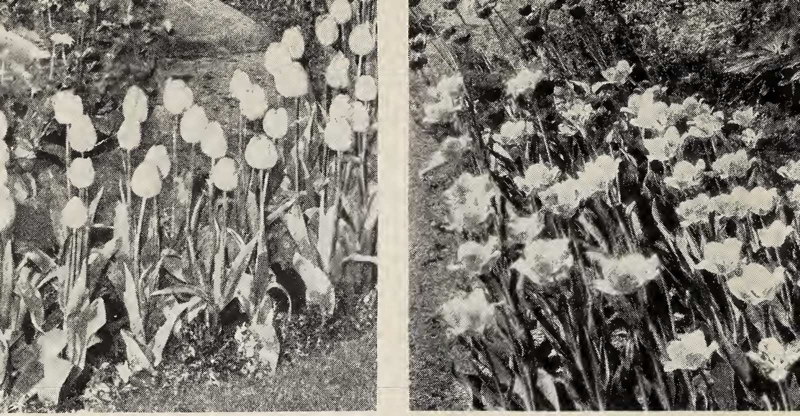
When a scientist talks about the behavior of living things, he is using the word "behavior" in a different way from the way in which you ordinarily think

These elephants had been in a dry place for a long time. When they finally came to the water, they drank gallons of it. They sprayed it over one another with their trunks. They rolled in it. They filled the air with squeals. All of these actions are ways of behaving.

of it. For example, if a scientist asked you to describe the behavior of your dog, he would want you to answer such questions as these: What does your dog do when you scratch his head? How does he act when he sees a cat? How does he act when he is hungry and you offer him food? How does he act if he is thirsty? What does he do when you come home after you have been away all day? How does he act when you scold him? How does he act when you are teaching him to do a trick? What things does he do that have never been taught to him?

All these actions of the dog, or of any animal, are known as its behavior. When you describe a dog's behavior, you tell what he does when something happens to him. Sometimes the things that happen to him are inside his body. For example, he may feel thirsty or hungry or sick. Because of these feelings he acts in some way. Things that happen outside his body also make him do things. For example, he may hear a noise, smell an odor, see a rabbit, or be hit with a stick. When these things happen, he may bark, growl, run away, wag his tail, or do other things. He behaves in certain ways because things have happened either inside his body or outside his body. Now do you begin to understand the scientific meaning of the word *behavior?* Suppose you think for a moment about your own behavior. How would you describe it? Think about such questions as these: What do you do when you are cold, or hungry, or thirsty? What do you do in hot weather that you do not do in cold weather? How do you behave when something happens that you do not like? What do you do when you

When the chair suddenly turned over, this little boy laughed. What things make you laugh? How do you behave when someone falls or drops a book?



Tulips close up when the sun goes down, but open wide in bright sunlight.

touch a piece of hot metal? How do you act when there is a sudden, terrific noise? And most important of all, how do you decide what to do?

It has probably been easy for you to see what scientists mean by the behavior of animals. But you may be a little puzzled by the idea that plants have ways of behaving, too. Think for a moment about ways in which you have seen plants change. How do plants act when they do not get enough water? Did you ever see a plant that closes its flowers as the sun sets in the evening? Some plants do that. Many green plants will grow in the direction from which the most light is coming. Yes, plants behave, too. Things happen in them or around them, and they change in some way because those things happen. Later in this unit you will learn about some of the

The porpoises have learned that the man gives them fish from the bucket. How do they respond when they see him appear with the bucket?

ways in which plants behave. Scientists say that all plants and animals *respond* to things that happen in them and around them. The way they act, or respond, is called their behavior.

* * *

1. Describe the behavior of your pet dog or cat.

2. Tell your class about the behavior of some animals that you have seen. Can you tell what may have caused this behavior?

3. Describe the behavior of a dog when he (*a*) is hungry, (*b*) is afraid, (*c*) is angry, (*d*) is being scolded, (*e*) smells the tracks of a rabbit.

A shout of "Help!" and hands splashing in the water are the stimuli that bring the little dog Mike to the rescue.

What makes plants and animals do things?

BEFORE YOU go any further, there is another word that you need to learn. You have been reading that "something happened" or "things happened" to make a plant or animal behave. We need a word to stand for these "things that happened." Scientists use the word *stimulus*. The plural is *stimuli*. Sound is the stimulus that makes your dog come when you call him or whistle to him. Cold, heat, and light are all stimuli. Stimuli are like messages that come to us, and we do things because we receive these messages.

You and your classmates can try some experiments to discover what some of these stimuli are and how animals respond to them. The experiments can be done either in your classroom or at home. For your first experiment fill a medium-sized plant jar with soft earth from a garden. Find several earthworms

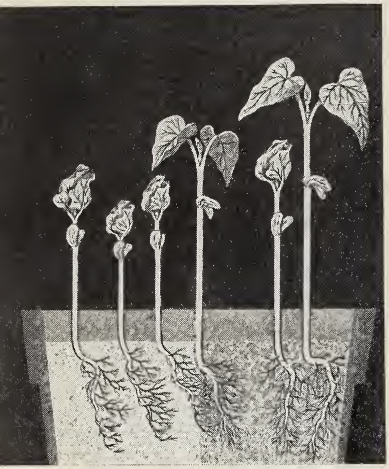
The frog is responding to the stimulus of seeing a moving butterfly. His sticky tongue flicks out, and the butterfly is caught for his meal! The grouse is responding to the stimulus of cold by fluffing out her feathers to make a thick, warm covering.

and lay them on top of the soil. Watch them. Where do they go? Can you tell why?

For your second experiment find a shallow box about a foot square. Fill one end of the box with dry earth and the other end with damp earth. Place some earthworms on top of the soil in the middle of the box. Which way do they crawl? What was the stimulus? How did the earthworms respond?

If your experiments were done carefully, you found that earthworms responded to the stimulus of light by crawling away from it. You also found that they responded to the stimulus of moisture by crawling toward the damp soil. Can you plan an experiment to show how earthworms respond to the stimulus of heat and of cold?

You can tell how an earthworm responds to another kind of stimulus by this easy experiment. Let an earthworm crawl along a wet piece of paper. Then dip a splinter of wood in vinegar and hold it about an inch from the earthworm's head. Try the same thing with ammonia. Did the earthworm respond to the stimuli of the vinegar and the ammonia by crawling away from them?



How did the plants respond to the stimulus of fertilizer in the soil at the right?

Do plants respond to different kinds of stimuli? Get a large flower pot and put a cardboard partition in the middle of it. Mix some soil with fertilizer and put the mixture in one half of the pot. In the other half put sand. Now pull the partition out and plant some bean seeds in the middle of the pot. Also plant some of the seeds in the rich soil and some in the sand. After the plants are two or three inches high, examine the roots. Did they grow toward or away from the soil containing the fertilizer?

When you taste or smell things, you are getting different kinds of stimuli. You pucker up your face and your mouth "feels funny" inside when you suck a lemon or take a spoonful of vinegar. When you taste something that you do not like, you sometimes respond to the bad-taste stimulus by spitting it out. You sometimes "hold your nose" because of the stimulus of a bad odor. Bad tastes and odors may even make you behave by becoming "sick at your stomach."

Try to think of other examples of how living things respond to different stimuli. What happens on a summer night if your porch light is turned on? Swarms of insects come to the light from the surrounding darkness. These insects respond to the stimulus of light. Some will even fly into the light and be killed by the heat. But not all animals respond to the stimulus of light by coming toward it. You remember how the earthworms responded to light in your experiment on page 24. The stimulus of light made them respond by burrowing

To what stimuli is this boy responding?

down into the dark earth. If you dig a ground mole out of its tunnel and lay it on the ground in the sunlight, it will immediately begin to dig down into the earth away from the light.

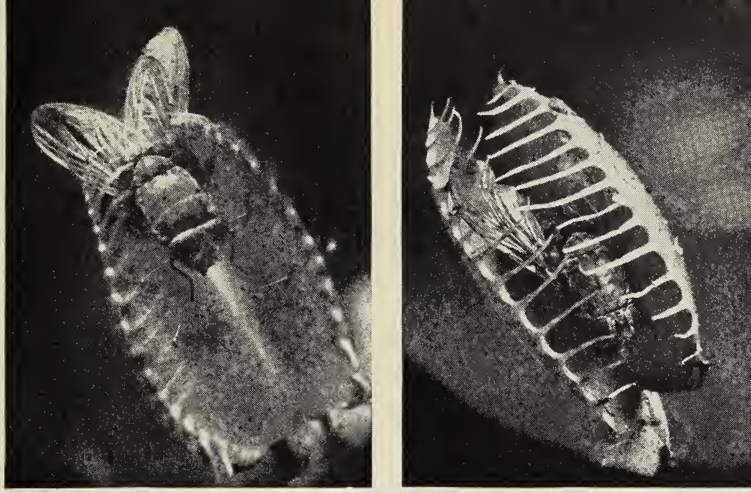
Perhaps you can think of some time when you yourself have responded to the stimulus of light. If you are looking toward the sun, you probably squint. Or you may put your hand up to shade your eyes. You respond to the stimulus of light, but you respond differently from the insect, or the earthworm, or the plant. Another example of your response to a stimulus is your behavior when you are thirsty. The lining of your throat becomes dry, and you respond by drinking water. Every living thing has its own way of behaving when its body receives some stimulus.

1. Tell what these stimuli cause earthworms to do: light, moisture, ammonia, vinegar.

2. Give examples to show that responses to stimuli are not always toward the stimulus.

3. An earthworm placed in a jar of soil on a piano will draw back into his hole if a note on the piano is struck loudly. Can you explain why the earthworm behaves in this way?

4. How do you think scientists have learned about the ways animals respond to different stimuli?



Here is a leaf from a fly-trap plant. Inside the leaf are several little hair-like spines. When a fly or other insect touches these spines, the leaf closes up and catches the fly inside.

How do plants behave?

Look again at the pictures of the "trick" plant that you read about on page 18. At the left you can see how the plant usually looks. At the right you can see how the plant looks after Ruth has brushed her fingers through the leaves and branches. The plant is called a *sensitive plant.* If you know what "sensitive" means, you can understand why the plant is given this name. It responds to the stimulus of touch by closing its leaves and drooping its branches. After awhile, if it is left undisturbed, the leaves and stems will return to their original position.

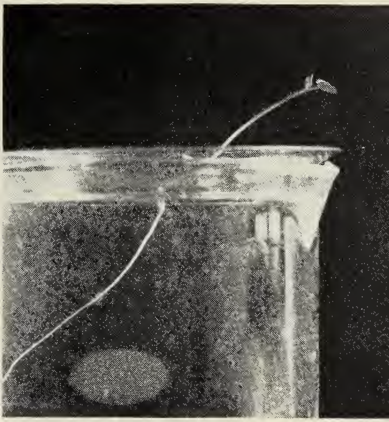
Ruth discovered one day that the plant leaves would fold up if she blew against them. When she took the plant out-of-doors in a strong wind, its leaves folded up, too. Try to buy a sensitive plant at a greenhouse or buy seeds and grow one. You will find it very interesting to watch.

Watching a sensitive plant is one of the easiest ways to see that plants can respond to stimuli. Do you know any other examples of how plants behave? Suppose you do the following experiments. For your first experiment find a small pasteboard box just large enough to hold a shallow dish. The box should be about three inches deep. Cut a hole in one side of the box so that light can enter. Now place several pieces of moist blotting-paper in the bottom of the dish and lay a dozen or more bean, radish, or grass seeds on the moist paper. Cover the box. Be sure to use good seeds and keep them moist. Watch the sprouts to find in which direction they grow.

If you have done your experiment carefully, you will find that the sprouts from the seeds grow toward the light which comes through the hole in the side of the box. If the distance is not too great, the sprouts may even grow through the hole into the light. What does this tell you about the behavior of plants toward the stimulus of light?

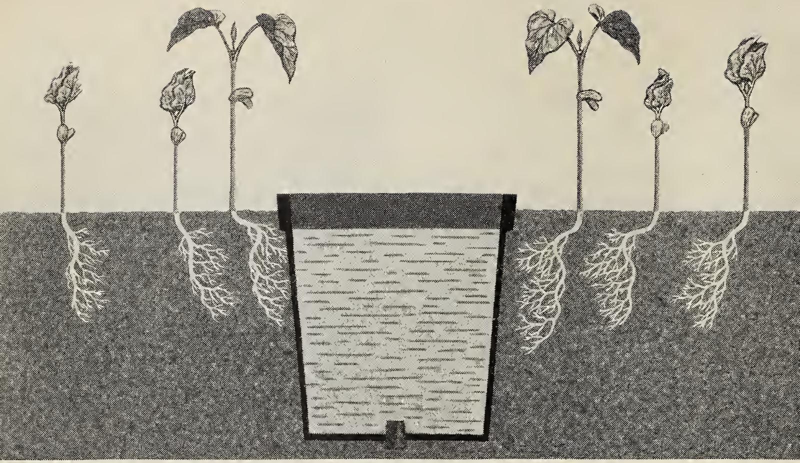
Another experiment will show you more about how plants respond to the stimulus of light. Use a

This picture shows how a young plant grew from a seed when it was lighted from the right. You can see that the stem grew toward the light and the root grew away from the light.



small geranium or any kind of house plant and put it in a window for a few days. Notice how the leaves turn. After most of the large leaves have turned toward the light, turn the plant around so that the leaves face the room. Now watch the plant again. How long does it take for the leaves to turn toward the light? Try putting a whole plant in a box that has a hole in it. What happens to the leaves on the plant?

Light is not the only stimulus that can make plants respond. Did you ever bring a pot of blossoming tulips into a warm room from a cool one? The tulips will open in a very few minutes if the room is warm, and they will close again if they are taken back into a cool room.



The bean plants in the first box in the experiment below should look like this when they are several inches high.

Try the following experiments, and you will find how the roots of plants respond to another stimulus. First, find a small unpainted flower pot and plug the drain hole with a rubber stopper and sealing-wax. Place this empty flower pot in the middle of a box about two feet square, and fill the box around the flower pot with rich earth. Plant several seeds near the pot and several seeds farther away from it. The soil needs to be moist when the seeds are planted, and it is a good plan to soak the seeds overnight before you plant them. Now pour water into the flower pot. It will slowly soak through the walls of the pot into the earth that is near it. Do not water the soil in any other way.

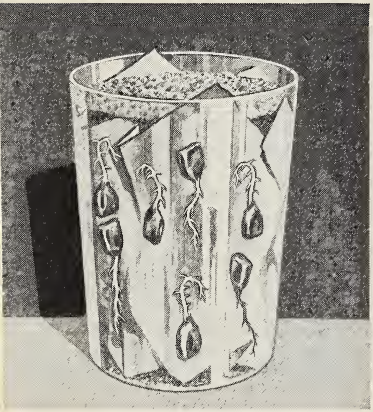
Now find another box the same size. Put the same kind of rich earth in it, but do not put a flower pot in the box. Plant the same kind of seeds in this box and plant them in the same way. Water the plants by sprinkling water on top of the soil. The only difference between the two boxes is in the way the roots get their water. If there is any difference in the way the roots grow, the difference will be caused by the way you have watered the plants.

After the plants are several inches high, dig up some of them that are growing near the flower pot. Be sure to notice in which direction the roots are growing. Now dig up some of the plants farther from the flower pot. In which direction do their roots grow? Last of all, examine the roots of the plants in the box without the flower pot. How do they differ from the other roots? Can you use what you have learned to explain what happened in the following story?

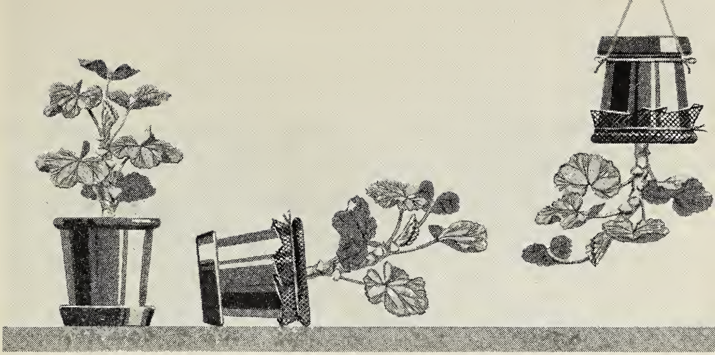
Some people built a house in a grove of poplar trees. They put tile pipe in the ground to carry waste water from their house to the street. After a few years they began to have trouble. The waste water would no longer flow from the house. It even backed up and flowed out on the basement floor. When they dug a trench down to the tile, they found that the roots of the trees had grown through the joints in the tile pipe. Inside the tile they had grown so big that they had filled the tile and broken some of it. Can you explain why the roots grew into the tile pipe?

You have seen that roots respond to the stimulus of water by growing toward it. Try to think of places where you have seen this happen. Have you ever heard of the roots of trees growing into cisterns?

Here is an experiment to show you how plants respond to another stimulus. Follow the directions carefully. Line a glass tumbler with moist blotting-paper. Then fill the tumbler with moist sawdust or sand. Soak some corn seeds overnight and place them between the sides of the glass and the blotting-paper. Use a dozen seeds and place them about an inch apart. Put the glass tumbler in a warm place and keep the sawdust moist. After a few days examine the seeds. Which way do the roots grow? After the roots have grown an inch long, lift half the seeds out of the glass and put them back so that the roots point upward. Watch the roots for two or three days. What do they do? Can you tell why?



Do the roots in your experiment turn and grow down again like this?

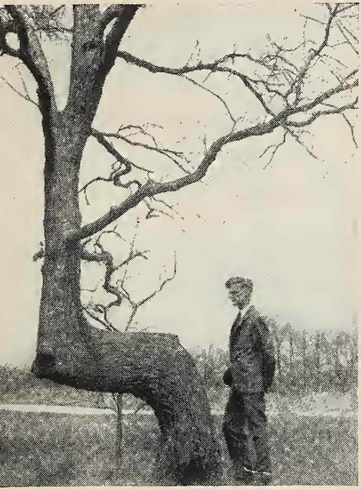


Watch your experiment carefully to find out which way the second and third plants grow after they are turned over.

The roots of the seeds that were left in the glass kept growing downward. When the roots were turned so that they pointed up, they turned around and began to grow downward again. The roots were responding to a stimulus. Do you know what this stimulus was? It was the pull of gravity. The roots of the plants responded to the stimulus of gravity by growing downward.

Try this experiment, and you will find out how other parts of a plant respond to the stimulus of gravity. Get three small geranium plants. Select plants that are growing well in small flower pots. Cut some wire screen and fit it around the stems of two of the plants and over the top of the flower pots. Fasten the screen on the pots with wire. This will keep the soil from falling out during your experiment. Water the plants. Now take one of the plants with the screen over it and lay it on its side. Hang the other one up so that its stem is pointing downward. Keep the third plant growing in a natural position.

Water all three of the plants whenever they need it and watch them for several weeks. In which direction does the stem of the plant in its natural position grow? How has the stem of the plant that is hanging changed its direction of growing? Has the stem of the plant that is lying on its side changed its direction of growing, too?



When this tree was a small sapling, it was bent over by Indians to mark a trail. The tip of the tree did not grow down. It bent again and grew up.

Probably you cannot tell what has caused the stems of two of the plants to change their direction so that they again grow upward. You have noticed, of course, that the stems of all plants grow upward and that roots grow downward. Scientists say that both the stems and the roots are responding to the stimulus of gravity. But they are behaving in different ways. The roots grow down, and the stems grow up. You remember that certain insects responded to light by coming toward it, and that earthworms and moles responded by going away from it. You can see that different kinds of animals behave differently toward the same stimulus, just as different parts of a plant may behave differently toward the same stimulus.

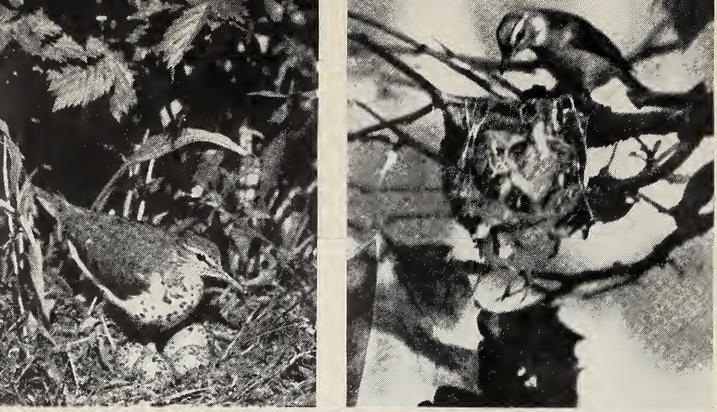
Later in your study of science you will learn more about the behavior of plants. Here you have learned that plants respond to different stimuli. You know now that even though plants cannot jump through hoops or get out of boxes they do have certain ways of behavior.

* * *

1. How do the roots of plants respond to the stimuli of water and gravity? How have you shown these responses by experiments?
2. How do the responses of a plant to stimuli help it to grow?

How do animals behave by instinct?

On page 17 you read about the tricks that Bob taught his dog. You can understand a dog's tricks because you know that someone has taught him to do them. But most of the animals in the world are never taught any tricks, yet they do many wonderful things. For example, have you ever watched the larva of a moth make a cocoon? If you

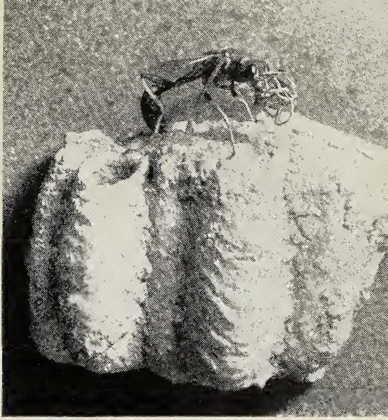


Birds do not learn to build nests from other birds. Yet the sandpiper always makes a nest on the ground, like the picture at the left, and the vireo always weaves a bag of down and leaves and swings it from a high branch. Each bird makes its own nest in its own way.

have, you know that after the larva has eaten food for several days, it becomes quiet for a time. Then it begins to form a cocoon of silk threads around itself. Slowly the larva is wrapped in the layers of thread, until finally it is completely enclosed. If it is the larva of a cecropia moth, it arranges the threads at one end of the cocoon so that when it has become an adult moth, it can easily squeeze out.

The larva has never seen its parents, and it has never watched another larva make a cocoon. It does not even know that it is soon to go through a great change and finally come out of the cocoon as a beautiful moth. Can you explain this behavior of an insect?

Before we try to explain this kind of animal behavior, let us think of other examples of the same kind of behavior.



This mud-dauber makes her cells, stores them with food, and lays her eggs in them. No one ever taught her how to do all this. Yet she does it just as all other mud-daubers do.

Some one may have told you that a mother bird teaches her young to fly. But if this were true, how could birds whose parents are killed ever learn? Birds often fly out of their nests when the parents are away gathering food. As soon as the young birds' muscles are developed, they can fly. They may be awkward at first, but soon they fly perfectly.

Do you know how a young beaver learns to swim? The only way young beavers can get out of their home is to swim, because the tunnel that leads out of a beaver house is filled with water. When the young beavers are strong enough, they dive into this tunnel of water and swim until they come up outside the house. How do you think they learned to swim?

When you try to explain this kind of behavior of animals, you may say, "It's the nature of the animal" or "It's his natural way to act." Scientists explain these actions by saying that the animal is born

Beavers cut down trees, build dams to make lakes, and build their houses. They do these things by instinct.

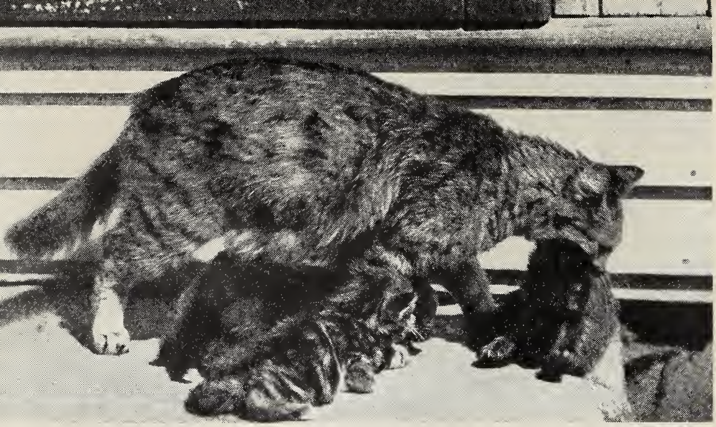
with the ability to act in these ways. Acts of this kind are called *instincts*. Instincts do not have to be learned, and animals do not think when they behave by instinct.

The larva of the moth does not plan its work by thinking, "Now it is time to stop eating. I must make a cocoon around myself because I am going to change to a moth." The larva does not know anything about its life. It behaves entirely by instinct. It responds to some kind of stimulus and eats. Some other kind of stimulus makes it stop eating and be quiet. Still another kind of stimulus makes it begin to spin a cocoon. In fact, the larva behaves almost

These young mallard ducks could swim an hour after they were out of their shells.

like a machine. The stimuli are like push-buttons. You push a button, and a bell rings. It always does the same thing every time you push the button. A stimulus comes to the larva, and the larva does something. It always does the same thing for the same stimulus.

Animals are born with certain instincts. All they seem to need is some stimulus to start them behaving according to their instinct. A kitten that is taken away from its mother when it is still young will catch mice for food as soon as it is old enough to do so. The mother has never taught the kitten to catch a mouse. It is born with the ability to catch mice, and the sight or odor of a mouse is a stimulus to start the instinct going. Spiders spin webs exactly like those built by their parents, grandparents, great grandparents, and all their ancestors, because of their instinct for web spinning. Ducks and turtles can swim when they are very young. They have an



A mother cat does not need to learn how to carry a kitten. By instinct she picks it up with her teeth, holding it by the loose skin at the back of its neck.

instinct for swimming. Water is the stimulus that starts them behaving by instinct.

Some animals *hibernate.* They respond to the cold of winter by burrowing into the ground and staying there. Frogs and toads dig down into the soft mud of ponds or streams. Sometimes when kept in a schoolroom during the winter they bury themselves in the box of soil where they are housed. They behave by instinct just as they would have done outside in the cold.

Some kinds of bears hibernate, too. The bear digs a hole in the ground or finds a cave in which it sleeps during the cold months. As long as the bear is quiet, it needs only a little food to keep it alive. This food is supplied by fat stored in its body.

In the autumn many birds fly south. Each bird does not start in a southerly direction. Birds fly over definite routes called migration lanes. And each kind of bird has its own place for spending the winter. The robins go to the southern part of the United States, but the little ruby-throated humming bird and the oriole fly across the Gulf of Mexico to Central America.

Scientists do not know exactly why birds migrate. There seem to be several stimuli which send birds on these long journeys. One of these is lack of food. Insect-eating birds would find few insects when the ground is frozen and covered with snow. Yet most of these birds start south in late summer when insects are plentiful.

Other stimuli are probably cold and light. We do not know for certain which stimuli start a bird on its migration. We do know that it is instinctive for birds to do this.

Scientists have discovered where birds migrate to by bird-banding. They capture a bird and put a small aluminum band around its leg. This band has a number on it. Then when the bird is recaptured the finder reports the number and the date and place where it was found.

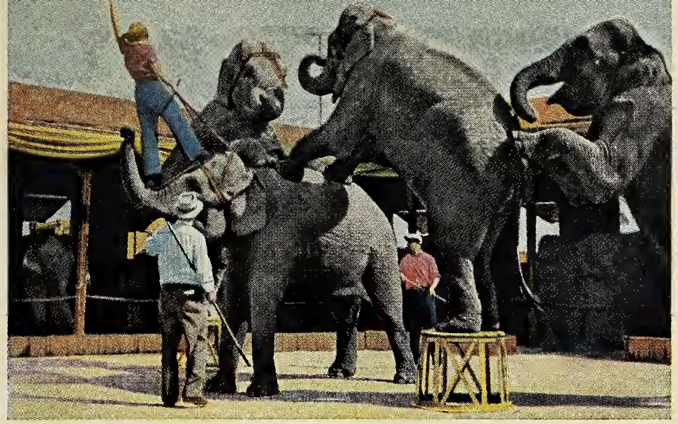
Many animals behave entirely according to their instincts. They cannot learn; they cannot think. All during their lives they do exactly the same things

This is a trick that many animals do by instinct. These young terns are not old enough to fly, but they know how to hide themselves. They stay perfectly still, and so it is almost impossible to see them among the rocks.

over and over again. But some animals, as you will see in the next part of this unit, can learn how to do certain things. Scientists are still trying to find out more about the instincts of animals and of people.

* * *

1. Tell as well as you can what you think an instinct is.
2. Some people believe that young animals always learn their behavior from their parents. Can you explain how this is often impossible?
3. Make a list of all the examples of instincts that are given in this part of the unit. Have you ever seen examples of animals showing these instincts?
4. Give an example to show that an animal is not thinking when it acts by instinct.



Animals can be taught to do many tricks. The behavior of these elephants is not from instinct. Their trainers have patiently taught them to go through the right motions by making them do them over and over again.

How do animals learn?

WHEN YOU think of learning, you probably think of reading something and remembering it, memorizing a poem and reciting it, or finding out how to solve a problem in arithmetic. Do you know whether animals are able to learn things? Of course you know that they cannot read, memorize a poem, or solve an arithmetic problem, but some animals are able to learn certain kinds of things. For example, Bob's dog learned to sit up and bark for food. Sitting up and begging for food are not instincts with a dog. They are not natural ways for the dog to behave.

Scientists have done many kinds of experiments to discover how animals learn. Here is a story of one of these experiments. A scientist placed a hungry cat in a box and then put food for the cat just outside the door of the box. He fixed the door so that it would open if a cord was pulled that hung down into the box just inside the door. The cat could see the food through the bars of the door.

The cat's hungry feeling and the odor of the food were stimuli, and the cat began to respond to these stimuli. And what do you think it did? First it tried to squeeze through the bars of the door but found that they were too close together. Then it stuck its paws through the bars and tried to reach the food. When this failed, it jumped from one side of the box to the other side. It went through these same motions over and over. Then quite by accident the cat pulled the string, and the door opened! This happened in exactly three minutes by the scientist's watch.

When the scientist put the cat in the box again, it went through the same motions, until again it accidentally pulled the cord. Every time he put the cat in the box, the cat got out a little more quickly. The animal actually seemed to be learning to pull the cord. Finally it could get out of the box in five seconds. By trying first one thing and then another, the cat had slowly learned how to get out of the box. It had never heard the old saying, "If at first you don't succeed, try, try again." But that was about the way the cat succeeded. Of course, the animal

How are these kittens trying to solve their problem? By what accident do you think they may finally succeed?

was not doing any thinking and planning. It succeeded by accident; it learned by accident.

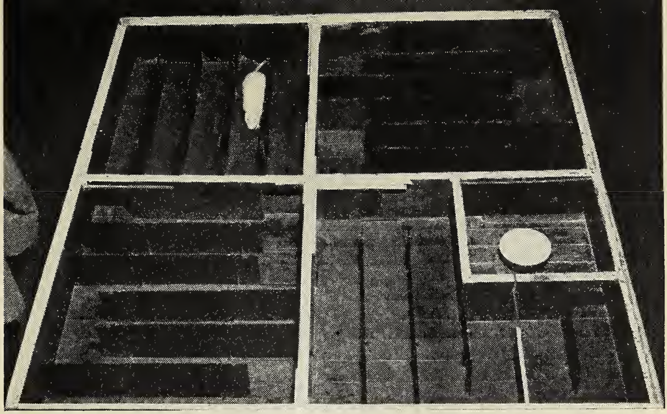
You can describe the cat's way of learning as a *trial-and-error* method. The first time the cat was put into the box, it behaved in many ways that did not help it to open the door at all. But each time it was put in the cage, it left out some of the useless motions until finally it pulled the string almost as soon as it was put inside the box. The cat had learned to open the box.

Of course the cat did not solve the problem of getting out of the box as you would have solved it. The animal could not think: "This door is closed by a latch. There is a string fastened to this latch. Let me see where it goes. Oh, there it is! It goes up over this nail and hangs down into the cage. All I need to do is to pull this string and the door will open." Instead, the cat first tried all kinds of things. At last one of them happened to work.

Scientists believe that animals learn many things by this trial-and-error method. Some stimulus comes to them, and they respond to it. Accidentally they do something that gets them what they want. When the same stimulus comes again, they do the same thing, and again they get what they want. Or a stimulus may come to an animal, and the animal may act in such a way that it hurts itself or that something unpleasant happens to it. When the same stimulus comes to the animal again, the animal will not do what it did the first time. In other words many kinds of animals are able to profit by their experiences.

The picture on the next page shows one way in which scientists study animal-learning. Rats are often used for this kind of experiment. The rat is placed in one side of a box like the one pictured. In the other side of the box there is a dish of food. In order to get to the food the rat must find its way through the passageways. All but one of the passageways are "blind alleys." They do not lead anywhere. There is just one path that will lead the rat to the food.

How do you think a hungry rat acts if it is put into a box like this? Usually the rat begins to explore



If the rat turns the right way each time he comes to an opening in these passageways, he will finally come to the pan of food. After many trials he learns to run through the passageways without making any wrong turns.

by going through some of the paths. When it gets into a blind alley, it comes back and tries another way. Finally, after several trials and errors it reaches the food.

The next time the rat is put into the box, it makes fewer errors. It finds the right path in a shorter time. And finally, after many trials, it learns to run through the whole series of passageways without making any mistakes at all.

Similar experiments have been done with animals that are very different, such as crayfish, ants, and baby chicks. All of them behaved in much the same way. Some animals were smarter than others and learned more quickly, but they still used the trial-and-error method of learning.

These experiments and hundreds of others that have been made seem to show that animals can learn things through the trial-and-error method. When they are trying to solve a problem, they try many things. By accident one thing finally works. Gradually the animal learns to stop doing the useless things and does the one thing that is successful.

* * *

1. How did the cat solve its problem of getting the cage door unlatched? How is this behavior different from the behavior of the Baltimore oriole when she builds her nest?
2. How do scientists find out how animals learn?
3. Give three examples of trial-and-error learning. Try to think of some other examples that are not given in this book.
4. Why do you think it takes so long for animals to learn to do tricks?

How is your behavior like the behavior of other animals?

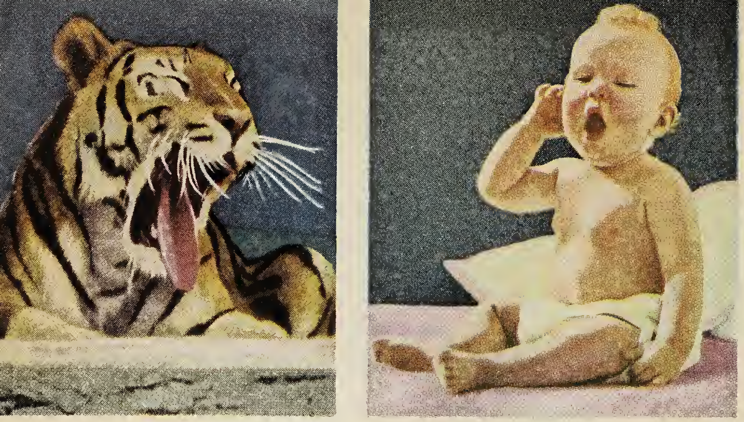
PERHAPS YOU have been thinking that you are very different from cats, dogs, insects, and earthworms in the way you behave. You are different in certain very important ways, but you may be surprised to find that in many ways you behave much like all other animals. Before you find out how you

These boys are not thinking about what they are doing. They make faces, gasp for breath, and make struggling movements with their bodies much as young animals do in wrestling with each other.

are different from other animals in the way you behave, let us see how you are like them.

Sit in a chair and place one leg over the other so that the lower part of the leg is hanging freely from the knee down. Then have someone strike your knee sharply just below the knee cap. Does your leg suddenly kick out? The stimulus of the blow made your leg respond before you could even think about it. When you prick yourself with a pin or a needle, you jump or you may even scream without thinking or planning to do so. When you accidentally pick up a hot object, you probably drop it instantly. You may even quickly draw in your breath from pain and shake your hand vigorously. Perhaps you scream or cry.

All these things you do without thinking. The

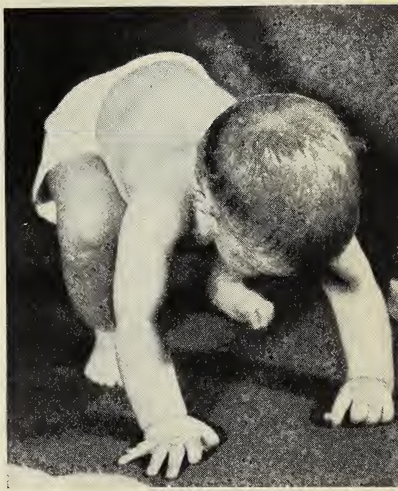


Neither the tiger nor the baby had to learn to yawn, and both do it without thinking.

stimulus of heat has made you behave in much the same way that any other animal behaves when it is hurt. In such cases you do not think any more than the dog or the cat thinks. People who are suddenly frightened, sometimes break out into a "cold sweat," a prickly feeling comes into their scalp, their hair feels as if it were standing on end, and "goose pimples" come out on their skin. They cannot help these things. The stimulus comes, and they respond like a door bell when the button is pushed.

Did you ever learn anything by trial-and-error? Do you ever solve any problems that way now? Of course you cannot remember how you learned to walk. But perhaps you have a baby brother or sister whom you have watched while he was learning to walk. Certainly he used trial-and-error as he found out how to balance himself and how to move one foot ahead of the other. A few hard bumps taught him to be more careful. A few tumbles downstairs made him hang on to the railing more tightly or keep his hands against the wall as he learned this new way of going places. Trial-and-error helped you learn how to use a knife, fork, and spoon to get food into your mouth.

When you make a kite, do you always get just the right length of tail? Or do you try out the kite, and then pull it down and add tail or take some off? Perhaps you even work arithmetic problems by trial-and-error. If the answer is wrong, you try to work it another way. Perhaps you stumble along by trial-and-error until you get the right answer. Many times in life you have to use trial-and-error. You cannot see exactly how to do something, but you must make an effort. So you say, "I'll try it out and see whether it will work."



You learned to walk much as this baby is learning—by trying again and again until you succeeded.

Yes, you and the other animals behave very much alike in many ways. Sometimes when a stimulus comes to you, you do exactly what a cat or a dog would do. But boys and girls and men and women can do some things that no other living thing can do. In the next part of this unit you will learn how and why people are different from all other living things in the way they act.

* * *

1. Describe exactly how you feel and what you do when you are suddenly frightened.

2. Do you think that writing and reading are instincts? Explain your answer.

3. How do you respond when a brilliant light is suddenly flashed in your face?

4. Describe how you have responded to the stimulus of some very bad taste. There are a number of things you may have done. Tell about them.

5. You have read that animals can learn only accidentally by trial-and-error methods. What have you ever learned to do by trial-and-error? Did you ever make a good kite by such a method? Explain your answer.

6. What are some of the things your body does because of the stimulus of cold?

7. How is the trial-and-error method used in learning how to dive?

Soon this little boy will be able to write, a thing that no dog or cat or bird can do. Later on he will be able to read the writing of others.

How is your behavior different from the behavior of other animals?

THINK OF THE behavior of the earthworm, the dog, the cat, and the moth larva. Did any of these animals seem to be thinking about what it was doing? Were they able to plan? Animals cannot have ideas about things. They cannot talk to each other. To be sure, some of them give warning calls and make other sounds, but they cannot really speak to each other. Suppose a beaver happened to find a new and better way to build a house. He could not write a book about beaver house-building so that in later years other beavers could use what he had learned. If a dog learns a trick, he cannot tell other dogs how to perform the trick. He cannot think about the trick, and he cannot solve a problem by thinking about the problem.

You are different from these other living things, for you are able to think and to plan. You can think because you have a better brain than any other kind of living thing in the world. Whenever you need to solve a problem, you do not have to go blundering around in a hit-or-miss, trial-and-success manner. You can think carefully and then decide what to do. Usually you do not need to try many different ways to solve the problem because you can think carefully enough to tell which one will work. You make use of your brain to solve your problems. You can behave quite differently from these other living things because you have a better brain.

Suppose that you and a friend are carrying a long, heavy log. You come to a fence through which you want to get the log. Quickly you look things over and decide what you cannot do and what you can do. You know that the log will not go through sideways. You think about lifting it over, but you quickly see that some other way would be easier because the log is heavy and the fence is high. You say to your friend, "Jim, let's see if there is a hole somewhere in the fence." Sure enough, you find one. Then you quickly see another way to help solve your problem. You say, "Jim, help me push this end through the hole; then you climb over and lift up that end while I lift this end." You do these things, climb over the fence, and your problem is solved.

You did not just sit down and say you could not get the log through the fence. You did not try to lift it high above your head and push it over. The two of you did not push it all the way through from the same side. You "used your head," thought the problem through, and went at it in the quickest, easiest way possible. You were behaving like an intelligent human being because you thought and planned. Animals can learn how to do some things by hit-or-miss, accidental methods, but they cannot plan how to do a thing and then follow the plan.

Making plans and deciding how to carry them out helped these boys solve the problem of building their clubhouse.

There is another way in which your brain helps you behave differently from other animals. Animals cannot look ahead into the future, and do today what will be best for them tomorrow. They always do the thing that they want to do at the moment. Sometimes this is good for them, and sometimes it is bad for them. But intelligent people are always "counting the cost" of what they do. Suppose you have saved up a dollar toward buying a camera. Some Saturday a friend calls up and says, "The circus is in town. Let's go this afternoon." You know that if you go, the dollar will be spent. You want to go to the circus, and you want the camera. You are having a hard time to decide. But you look ahead. You think how long the camera will last you and of all the fun you will have with it. So you decide to give up the fun for today in order that you may have something better in the days to come.

We can all save ourselves and our friends much trouble if we think and plan ahead instead of stumbling along like an animal. Every day all kinds of stimuli come to us. Because we have brains to think with, we should try to respond to these stimuli in ways that will be best for us.

1. Choose some problem that you have had to solve and tell how you solved it and why you solved it the way you did.

2. Tell two ways in which you can behave differently from all other animals.

3. Why can human beings behave differently from all other animals?

How do habits help us?

Before you begin to study this part of the unit, think for a moment about the habits you have. You need not tell anyone what you are thinking, because you may have some habits that you are a little ashamed of. Of course you have some habits that are good, too. How do you "get into" these habits? How could you break the habits that are not good for you? Perhaps you are not quite sure what a habit is, even though you may have heard a great deal about "good habits" and "bad habits." The following examples of habits will make clear what they are and how they are formed and broken.

John began to get into the habit of staying in bed after his mother called him. The first morning it happened, he had been up late the night before, and he was very tired. The next morning he thought he would wait a few minutes before he got up. After he

Here is a good habit. The first response Jim makes to a "sneezy" feeling is to reach for his handkerchief.

had done this a few mornings, he kept on doing it. It had become a habit. John had not planned to get into this habit, but before he knew it, he was finding it almost impossible to get up when his mother called.

John also has the habit of brushing his teeth every morning. When he was a very small child, he learned to brush his teeth. At first, it was very hard for him to remember to do so; but as the weeks went by, it became easier and easier. Now he brushes his teeth every morning without even thinking about it.

Many of the actions of animals are habits, too. Your dog may have a habit of climbing into a chair to sleep at night, or he may have the habit of chasing your neighbors' cat or chickens. But there is one very important difference between animals' habits and your habits. Animals cannot think: "This is a bad habit. I will change it." But you can change many of your own habits.

You can often break a bad habit by forming a good habit to take the place of the bad one. First

This boy has formed the habit of keeping himself clean.

you must think carefully about the habit and be sure that you want to break it. Then, you must practice the new habit faithfully and be careful not to fall back into the old habit. Soon the new habit will become easy. John could have stopped his habit of staying in bed after his mother called him by getting out of bed at once. The first morning this would have been hard to do, but each morning it would have become easier and easier. Finally a new habit would have been formed.

When John was learning how to dive, he tried over and over again. When he began, he could not learn to jump so that he went into the water headfirst. He always landed in the water so flat that he made a great splash. Then his teacher began to show him how to dive correctly. He showed John how to let his body fall forward, how to hold his head and hands, and how and when to push with his feet and legs. The more John tried, the easier it became for him to dive well. John learned by trying over and over again to dive correctly. Once a person has learned how to dive correctly, he can make correct diving a habit. This can be done by always practicing the correct way of diving. Finally, correct diving will become a habit.

Good habits are very helpful to us. They save us much time and thinking. If we had to think about every little thing we do, we would not have much time left for other things. But when we are acting by habit, we do not have to stop to think and decide.

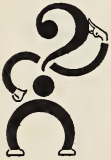
* * *

1. Describe to your class how you learned to swim, roller-skate, or ride a bicycle.

2. How can you change a bad habit to a good one?

3. Read the three sentences below. Then copy on the board the ones that are true and read paragraphs from this book that prove they are true.

a) It is very hard to change a habit unless you really want to change it.
b) Animals cannot plan to change their habits.
c) It is always easy to change a habit.



Questions to Answer

1. Would you believe an animal story that said, "The fox was planning to dig a cave for a home"? Why?

2. What have you learned to help you understand your pet dog's behavior?

3. How would you compare the behavior of a plant with the behavior of an animal?

4. How would you compare your own behavior with the behavior of a dog?

5. How can you learn to plan better?

6. Do you believe that the number 13 can bring you good or bad luck? Why?

Things to Find Out

1. Ask your teacher to help you make a list of good study habits. Keep the list and use it.

2. Make a list of rules that will help you work your arithmetic problems.

3. Some people believe that a horse hair will turn into a snake if it is left in the water. Plan an experiment to prove that this is only a superstition.

4. Try to teach your animal pet some kind of trick. Watch it closely to see how it learns.

5. Observe the behavior of several kinds of pet animals and describe this behavior to your class.

6. Find examples of how trees, shrubs, and other plants have changed because of light.

7. Make a list of good health habits. Which of these habits do you have?

8. Notice the arrangement of the leaves on a tree. What stimulus made each leaf turn the way it did?

9. Take a frog from a pond and place it on the ground several feet from the pond. Does the frog return to the water? How does the frog respond to the stimulus of water?

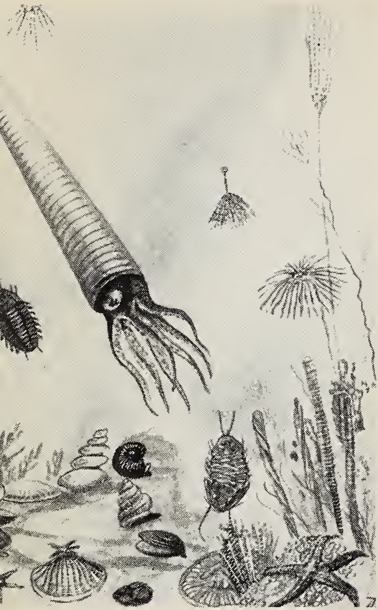
UNIT TWO

HOW HAVE LIVING THINGS DEVELOPED ON THE EARTH?

PERHAPS YOU have never wondered what the world was like 500 million years ago. Well, scientists have proved that it was here, spinning around like a top and whirling around the sun just about as it does today. But what a different world it was from the world that you live in! Can you imagine what the living things looked like millions of years ago? Perhaps you think that they looked about the same as the living things of today. But let us see.

Suppose that on a Saturday about 500 million years ago your class had decided to take a hike to discover things about animals and plants. If you had planned to collect different kinds of flowers, you would have been disappointed, because there were no plants with flowers in those days. None of the boys could have gone fishing, because there were no fish. You would not have needed field-glasses to watch birds in the trees. There were no birds; in fact, there were no trees!

If any boys and girls in your class had planned to hunt for wild fruits and nuts, they might as well

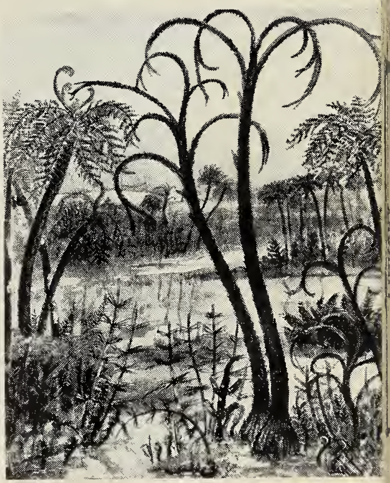


have stayed at home. No fruits and nuts grew then. Insect collectors would have come home empty-handed. They would not have been able to find any insects.

Perhaps you are wondering if you would have found any living things at all on this Saturday hike 500 million years ago. Yes, there were some living things, but they were small, and they lived only in the water. All of the animals and all of the plants 500 million years ago lived in the water. At that time great seas covered more than half of North America. If you had scooped a net into the water, you might have brought up some animals. For example, you might have brought up some sponges and a few jellyfish. These animals were common in these ancient waters. You might also have found several kinds of animals with shells like those in the picture on this page. Some of them looked much like the snails that you find in the water of lakes and streams today.

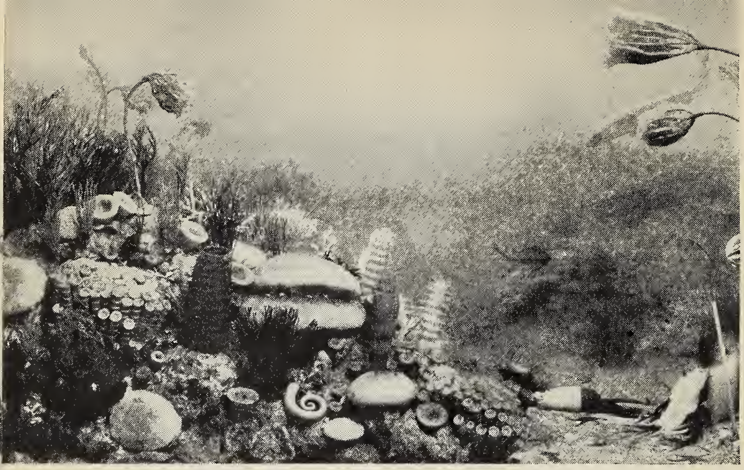
If you had rowed a boat, you would not have been troubled by thick reeds and other water plants. Plants of those days were very different from the ones of today. Most of them were very tiny plants that floated about in the water.

Now perhaps you would like to wait about 150 million years and take another Saturday trip. You will find that plants and animals have changed greatly since you made your earlier trip.



This time you will need to take a compass with you, for you may get lost in the forests of land plants that have developed. But do not expect to find trees like those of today. Most of the trees looked like the ones shown in the picture on this page. As you see, they were more like giant ferns than trees. You will still not be able to gather any wild flowers. No plants with flowers have yet developed on the earth.

You will have better luck looking for animals on this trip. You will find many kinds of sponges, jellyfish, and corals and also many kinds of snail-like



Here are some animals and plants that lived in the sea 350 million years ago. The flower-like objects near the top are really animals. Near those at the left is seaweed. The objects that look like cups, mushrooms, and clusters of tubes are different kinds of corals.

animals; so you can make a collection of shells if you like. Everyone in your class can take a fish pole on this Saturday trip. There were so many fish in this period of the earth's history that scientists call it "The Age of Fishes."

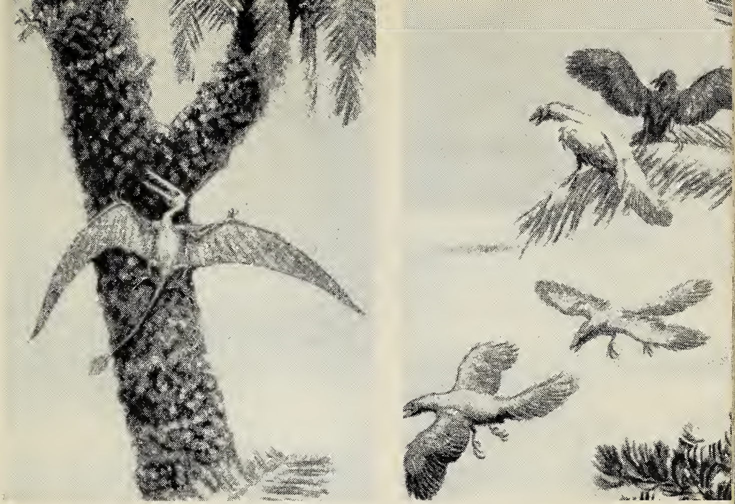
But do not expect to catch any trout or bass or sunfish. The fish 350 million years ago looked very strange. Some of them had both gills and lungs. They could live either on land or in water. Some had fins that looked almost like legs. These walked on their fins. Some were covered by very large and very thick scales. Instead of bones these fish had skeletons of tough cartilage.

Although a Saturday trip 350 million years ago would have been very interesting, perhaps you might have had a more exciting time on a trip only 150 million years ago. On this trip you would find that great changes had taken place. Many of the seas that formerly covered North America have disappeared, because the land has been pushed up above the water. Great mountain ranges have been formed, and the climate has become quite dry. You would see many new kinds of plants. Among them you would find a kind of tree that developed since your last trip. It is a cycad like those in the picture.

If you live in Florida, you have probably seen cycads. You may have heard them called palms, or sago-palms. When you look at one of these trees, you are looking at one of the oldest kinds of trees on the earth. More than a million years ago cycad trees grew almost all over the world. Today they are found in only a few places. They are important because they were the first kind of plant to grow seeds. They grew their seeds in cones, somewhat like the pine trees of today. At this time in the earth's history most of the plants were small.

You would find that animal life had changed greatly during the 200 million years that had passed since your last hike. There were plenty of water animals then, but you remember that you saw only a few land animals. This time there would be many. You would find plenty of insects for a collection, and if you were fast enough, you could catch frogs, toads, and salamanders. These amphibians had developed on the earth since your last trip. Amphibians, you remember, are animals that spend part of their lives in water and part of their lives on land.

You would probably not spend much time trying to find the small water animals and the amphibians, because you would be frightened by the reptiles. In and near the water you would see enormous turtles, but they probably would not frighten you so much as the other reptiles. Look at the pictures here and on page 64. One hundred fifty million years ago giant reptiles like these roamed the earth. Many of these were called *dinosaurs*. The word means "terrible reptile." Some of them



At the left is a small flying reptile, and at the right are some of the first birds. How are the birds like the birds of today?

were nearly a hundred feet long and probably weighed as much as forty tons.

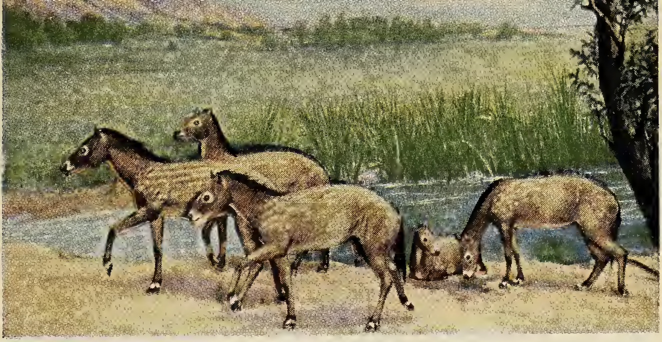
If you could watch these strange dinosaurs roaming over the land, you would see many different kinds. Some were covered with hard plates, some had long necks and long tails, some had fierce-looking horns. Some walked on their hind legs and used their front "arms" for grasping. You might see some kinds of reptiles eating leaves of trees and other plants. Others would be catching some of the smaller animals for food. You would probably be surprised to see a great animal with a wing-spread of twenty-five feet sail over your head. But it would not be a bird; it would be a flying reptile.

You would see birds, too, but you would not find any robins or crows. These "early birds" were very different from the birds you see today. But most of the animals would have been reptiles. There were so many kinds of reptiles on the earth 150 million years ago that scientists call this period the "Age of Reptiles."

You would never have noticed the mammals, or fur-bearing animals. There were only a few small mammals, no larger than mice, scurrying through the forests. If you wished to see many mammals, you would need to plan still another Saturday hike.

A Saturday trip about fifty million years ago would have shown you great changes. Flowering plants had developed on the earth. The fish looked much like the sharks found today. Frogs, toads, and reptiles were still found everywhere, but the great reptiles had disappeared. The lizards, snakes, and turtles were more like those which we have today. The birds, too, had become more nearly like the birds of today.

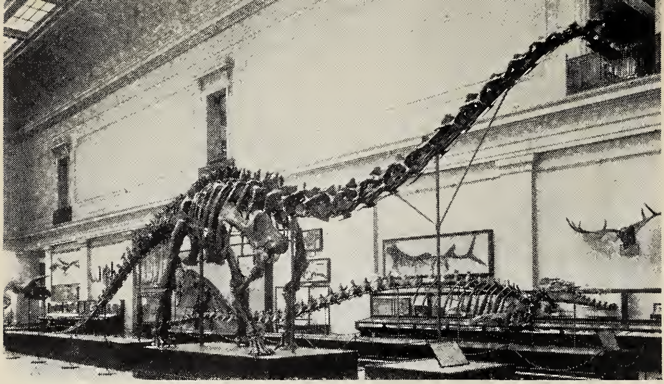
On this trip you would have found a great many different kinds of mammals. Some mammals were very large. There were elephants, camels, and even horses, but you might not recognize them, because they were very different from the elephants, camels, and horses of today. But the world of fifty million years ago looked in many ways like the world that you know today.



These little horses, about the size of a police dog, lived thirty-five million years ago. Since then mammals have made great changes. What changes can you see in the horse?

In these descriptions of imaginary trips of long, long ago, you should have learned three important things. Can you tell what they are? First of all, you should have learned that the earth is very, very old. Second, you should have learned that living things have been ever changing, changing, changing through the millions of years since life first began on the earth. The plants and animals that we have on the earth today are very different from the plants and animals of several hundred million years ago.

The third important thing is this: New kinds of living things have always been appearing on the earth. At first there were only water plants and animals. Then there were amphibians, then reptiles, then birds, and then mammals. For millions of years there were no plants with seeds. Plants had spores instead of seeds. Today there are more kinds of plants with seeds than there are plants with spores.

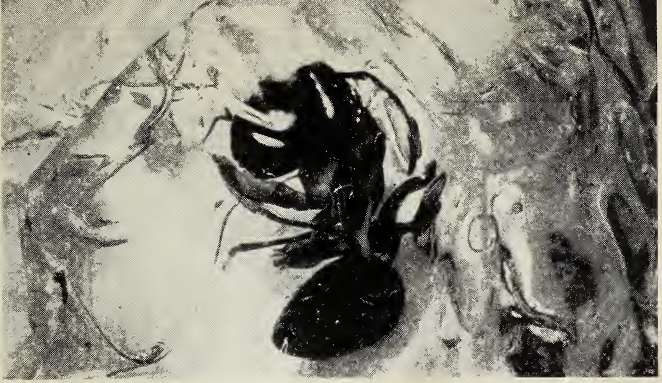


But do not expect to go out and see plants and animals changing during your lifetime. Remember that living things change slowly. The world that you live in today has had millions of years in which to become the kind of world that you know.

How do we know what the living things of the past were like?

PROBABLY you are saying to yourself, "All of this is very interesting, but how do you know it is true? How do you know that there were plants and animals like these? No one was there to see them." You are quite correct when you say that no one lived 500 million years ago. Of course, then, there was no one to write books or make records of what happened. But fortunately the animals and plants themselves made records that we can read. Have you ever seen any records made by these ancient living things?

The museum room shown in the picture on this page is full of the records that plants and animals



have made. Some of the animal records were made millions of years ago by the giant reptiles that roamed over the land. Some were made by the small animals that slid about in the mud of the sea bottom. Some were made by the queer birds that glided about in strange trees, catching strange insects. But how were all these records made? The living things of long ago had different ways of making these records of themselves.

On this page is a picture of the body of an insect that is probably at least 200 million years old! One day, long ago, this insect flew against the sticky gum of a tree and got caught. The gum kept oozing out of the tree until it completely covered the insect. Then the gum hardened. Hundreds of years passed, and slowly the gum hardened into another material called *amber*. The insect was still inside. One day a scientist looking for records of animals and plants found this lump of amber. He brought it to the

museum and polished it, and there inside was a perfect record of an ancient animal.

The body of this insect that was caught in the amber is called a *fossil.* All of the records of plants and animals in this museum room are fossils. A fossil may be the whole body of the animal, or it may be only a part of the animal. Sometimes fossils are only footprints of animals.

But insects were not the only kind of animals that became fossils. The picture on this page shows some much larger animals that got caught long, long ago. Millions of years ago there were great tar pits in what is now California. The pits were ponds of hot tar. Scientists say that they were covered with water. When the animals came there to drink, they reached out to get water, and their feet began to slip into the soft tar. Down they went, slowly sinking farther and farther into the pit.

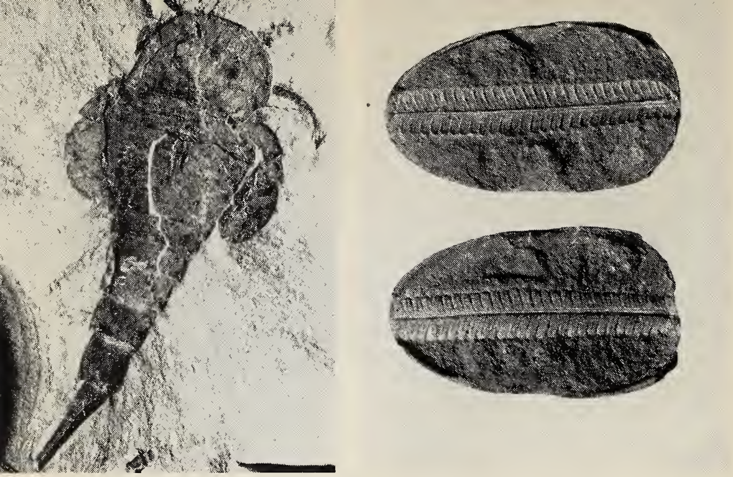
After thousands of years the tar cooled and became solid. Then, not so many years ago, men dug

into the tar and found the bones of these animals of long ago. Unfortunately the entire animals were not preserved. Only their bones became fossils.

There are still other ways in which animal fossils were formed. Some animals were caught in great holes in the ice in the far north. Here, where the ice never melts, the bodies of these animals have been kept for thousands of years. Mammoths like those in the picture have been found frozen in the ice.

Many fossils were made when dead animals and shells of dead sea creatures sank into the sand and were soon entirely covered. As the sand was turning into rock, these animal shells turned to stone. We say that they became *petrified*.

Often these ancient animals left only the *prints* or *molds* of themselves. Have you ever seen the print of a hand or a foot in a concrete sidewalk? A child or a dog may step into the soft concrete. When



At the left is the fossil that an animal made when its body settled and left its print in mud. Later the mud hardened into stone. At the right is the mold fossil of a leaf. The stone was split down the middle to show the two sides of the mold.

the concrete gets hard, the footprint is hard, too. The print in the sidewalk is a record of the animal that made it.

During the millions of years of the past, animals died, sank to the bottom, and made a print in the mud where they settled. Slowly the soft parts of their bodies decayed. Even the shells fell to pieces. But the print stayed in the mud because the mud had hardened. Finally this hardened mud changed into rock. In the rock was the print as you see it in the picture at the left. At other times the animal was completely covered with mud. When its body decayed, there was left in the hardened mud a hole

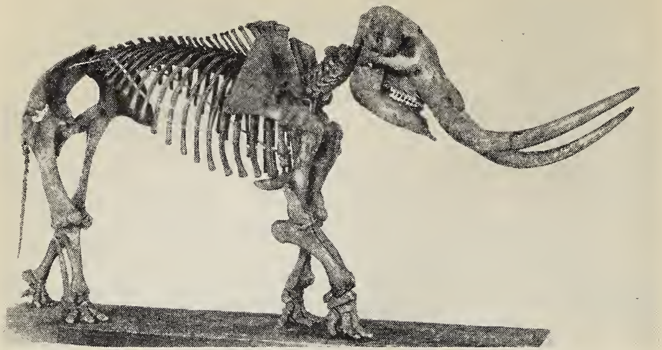
These petrified logs are in a desert in northern Arizona.

exactly the same shape as the animal's body. Such a hole is called a *mold* fossil.

You can understand how these fossil prints and molds were made if you take some clay soil and moisten it until it is soft. Then lay a shell on the soil and press on it until it makes a print. Lift the shell out carefully and set the clay in the sun. The clay will get hard, and you will have a print like a fossil print. If you use plaster of Paris instead of mud, you will have a print that you can keep.

Plants, too, left fossil records of themselves. The giant ferns left prints of themselves in stone and coal. Some of the cycads became petrified. They were buried under the soil and changed to stone.

Scientists have found thousands and thousands of

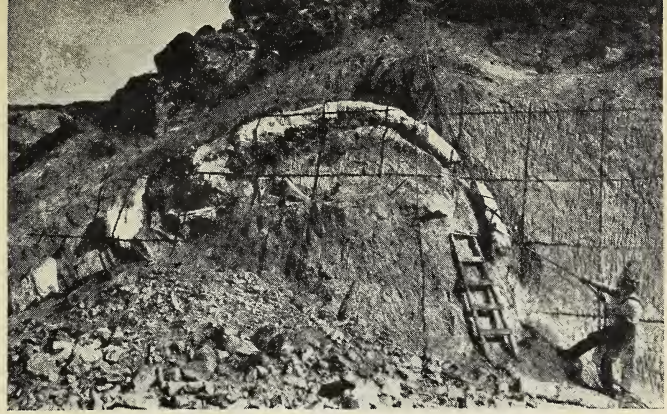


Here is the skeleton of an animal like that on page 77. Scientists have found thousands of fossil skeletons like this.

fossils in all parts of the world, and every year they are hunting for more of them. Along a roadside in Iowa a scientist gathered more than ten thousand fossils of small, ancient animals. Scientists once dug into a hill in Nebraska and found more than fifteen thousand skeletons of ancient mammals.

After scientists have found a fossil, they very carefully prepare it for the trip back to a museum. Sometimes they have to spend many hours chipping stone away from the fossil, because the mud that once surrounded the plant or animal has all been changed to stone. If the fossil is made of many different bones, they must be fitted together into the proper positions so that we can see what the animal looked like.

Fossils show us what the living things on the earth were like long, long ago. They are records that tell

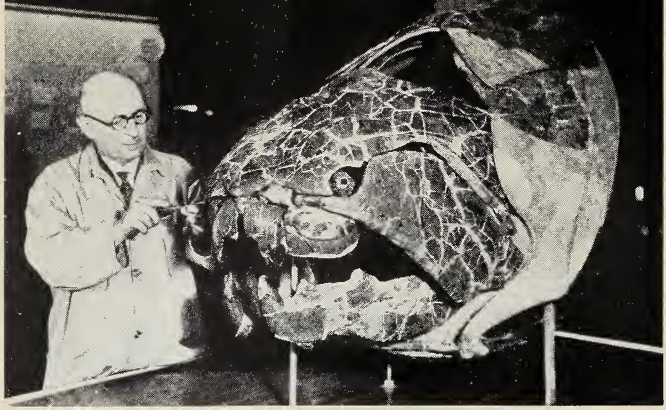


The bones of the skeleton shown on page 74 were carved loose from the rock and shipped to the museum. Before they were removed, squares were painted on the rock, and the bones were numbered. The squares and numbers were copied on a chart to help the scientists fit the bones together again.

us many important things about the earth as it looked millions of years before man lived on it.

The mountains in the western part of our country are many thousands of feet above the ocean. Yet in the rocks of these mountains scientists find fossil skeletons of fish and the fossils of other animals that once lived in the salt waters of the ocean. This means, of course, that these places must have been covered with water at some earlier time. Then something happened to raise these places up above the water. Do you see that the place where fossils are found tells us many things about changes that have taken place in the surface of the earth?

Scientists have found fossils of giant ferns, palms,



This huge fish lived 300 million years ago. The skull was found near Cleveland, Ohio. Fossils such as this tell scientists that this part of our country was once deep under water.

and other plants as far north as Greenland. After they studied the fossils and the rocks, in which they were found, the scientists decided that this vast, cold country was once covered with growing plants. The fossils showed that the climate of Greenland has changed greatly since these plants lived there. Today most of Greenland is covered with a sheet of ice hundreds of feet thick, but the fossils tell us that Greenland was once a warm country.

Scientists digging in the earth in Michigan have found parts of *coral* islands that were made by small sea animals. The animals that made these coral islands can live only in water, and they can live only in warm water. The discovery of the coral islands shows that this land was once under the water. The water of this sea must have been very different from the water in the Great Lakes. It must have been warm like the South Seas, where corals live today.

Fossils, then, can show us how the climate of places on the earth has changed from warm to cold or from cold to warm. They can also show us how the land itself has changed. By the study of fossils we learn that some of the land which is now dry was once under water. When fossils of sea-living animals are found on tops of mountains, scientists know that the mountains were made from rock that was once at the bottom of the sea.

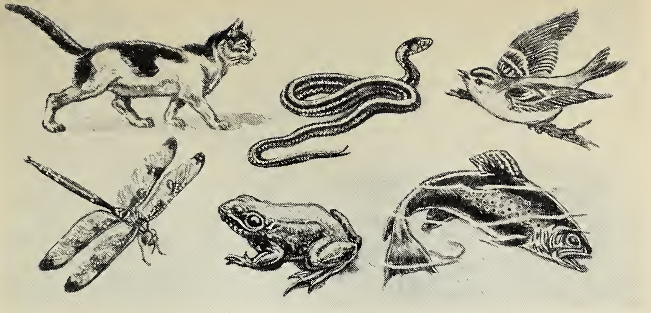
It is through a study of fossils that we know the story of animals and plants which you read about at the beginning of this unit. If scientists had never found the remains of these ancient living things, we would never have known what they looked like. The fossils of these animals and plants show how the ancient animals and plants were different from those of today. For example, look at the picture of ancient birds on page 71 and compare them with one of our birds of today. Can you see how these two animals are quite different from each other? Look at the picture of ancient trees on page 69 and compare them with modern trees. It is easy to see that these plants are quite different from each other.

Scientists spend much time studying fossils because they can find out important things about the history of the earth. They can tell how the water and the land have changed. They can tell how the climate has changed and how plants and animals have changed.

1. Explain what a fossil is.
2. Tell four ways that fossils may be formed.
3. What important things would the following discoveries tell scientists?
   - *a*) Finding the fossil of a sea animal in the rocks on top of a mountain.
   - *b*) Finding a fossil turtle and comparing it with a live turtle.
   - *c*) Finding sea animal fossils in a desert.
   - *d*) Finding the fossil of a fern and comparing it with a living fern.
4. Explain why we believe that the land of Michigan was once under a warm ocean.
5. What do fossils tell the scientist?

How have animals and plants changed through the ages?

You have learned that animals and plants have not always looked as they do today. They have changed greatly since the first living things appeared on the earth hundreds of millions of years ago. Many new kinds of animals have appeared, and many kinds of animals and plants have disappeared forever.

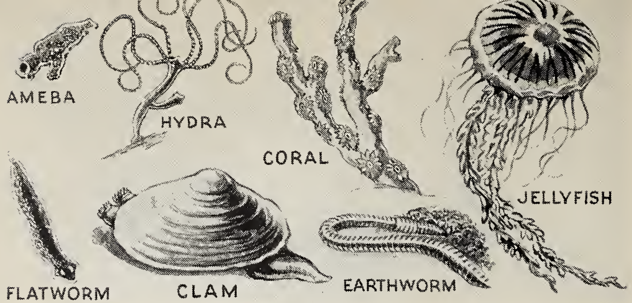


What body parts can you name in these animals of today? Compare these animals with the simple animals on the next page.

When scientists describe these changes in living things throughout the ages, they say "Animals in the beginning were very *simple.* Gradually they became more *complex.*" Let us see what this means.

You know that the animals and plants on the earth today are divided into several groups according to their structure. Fish make up one of these groups. Amphibians, reptiles, birds, and mammals are other groups. All of the animals in these groups have many, many parts to their bodies. They have many bones, muscles, and other body parts. All of the animals in these five groups have backbones. If you examine a fish, a frog, a bird, a reptile, or a mammal, you will find that each one of them has a backbone.

But there are other groups of animals that do not have backbones. Insects, crayfish, jellyfish, snails, crabs, and hundreds of others have no backbones, and they have fewer parts to their bodies; that is, their bodies are simpler than the bodies of animals



The ameba has only one cell in its body. None of the animals shown in this picture has such complex parts as legs, wings, or backbones.

with backbones. Some kinds of animals are so simple that they are made of only one cell.

On this page are some pictures that will help you see how animals are different from each other in structure. Can you find the simplest animal in the group? It is an animal called an *ameba*. If you compare it with the bird or the mammal, you will see some of the differences between a simple animal and a more complex one. The simple animal has only one part or a few parts to its body; the complex animal has many parts.

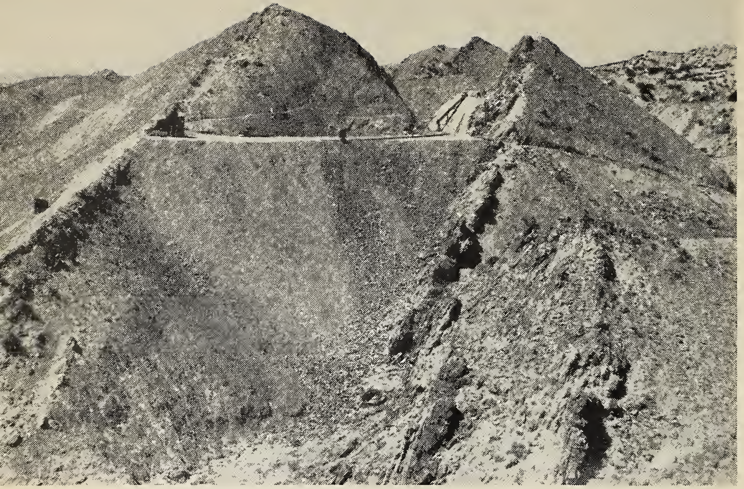
Scientists believe that the first animals on earth had very few parts to their bodies. The more complex living things came later. What makes them think that this is true? In many places on the earth scientists have been able to read the history of living things in the "book" of the rocks. They have studied the rocks in the great canyon of the Colorado River. We call it the Grand Canyon. At this place the

Scientists can learn much about the story of fossils by studying the rock layers in canyon walls like this.

waters of the river, working away for millions of years, have cut down two miles into the soil and rock of the earth. As they cut, they uncovered layer after layer of rock made millions of years ago. In these rock layers are the fossils of ancient animals.

Of course, some of these rock layers are much older than others. The oldest rocks are usually farthest down in the earth, and the newest ones are nearest the top. You can understand why this is true if you know how these layers were made.

Water from the land drained into the seas just as water drains into seas, oceans, and lakes today. This water carried mud, sand, and clay with it. Year after year these materials were carried into the water and settled to the bottom. When water animals and plants died, their shells and other hard



Here is the hillside where the skeleton on page 74 was found. In the center and at the left you can see how the rock layers have been pushed up until they are standing almost on edge. Near the top is a ladder that leads up to the skeleton beds.

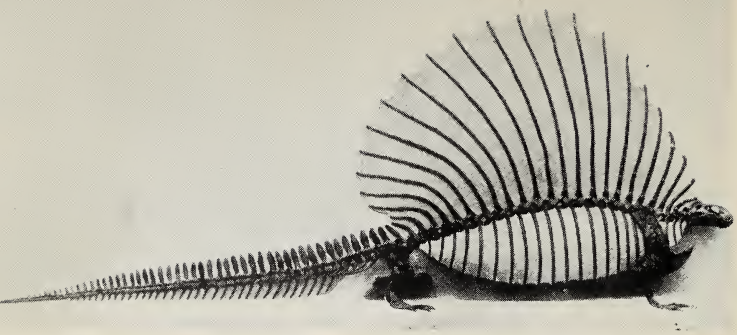
parts settled to the bottom, too, and were covered by mud. Slowly through millions of years all this sediment at the bottom turned to stone. It was pressed tight by the tremendous weight of the material above it. In this way a layer of rock was made. Because this kind of rock was made from sediment, it is called *sedimentary* rock.

After this layer of rock had been formed under the water, a strange thing happened. The land was pushed up, and the water ran off into lower places, leaving the rock as a top layer on dry land! Then, after long ages, the water would rise again and a new sea would

Many skeletons were found on the hillside shown on the opposite page, which is located in Utah. Most of the skeletons were not removed. The rock was carved away from them and they were left standing where they were found.

cover the layer of rock. Once more the particles of mud and sand and clay would be washed into the sea. Again they would sink to the bottom and slowly make a new layer of rock. In this layer would be fossils of the animals and plants that were living during that age. As each layer of rock is a little different in color from the others, scientists can easily tell where one ends and another begins.

Now you are ready to see what all this has to do with the Grand Canyon of the Colorado River. In very early times there were many layers of rocks formed in the region through which this great river flows. As the river flowed along, its waters began

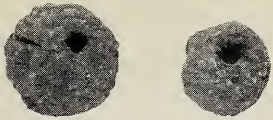


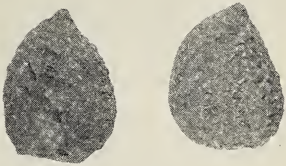
Many skeletons of "ship-lizards" like this have been found in Texas. Because of the rock layer in which they were found, scientists know that they lived 225 million years ago.

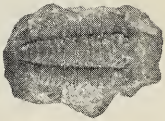
to wear away and cut through these layers of rock. Deeper and deeper it cut, until after thousands of years it had made a canyon two miles deep.

You can now understand that the oldest rock is usually at the bottom of this canyon and the newest rock is at the top. Many other places on the earth show rock layers like this. Perhaps you have seen them on the steep bank of a river or on the banks of a deep gravel pit. Sometimes a layer of rock is found which is older than the layer beneath it. This shows that at some time in the past there were changes inside the earth which folded this layer over the newer layer. But scientists can tell when one layer is folded over another layer.

The fact that scientists can tell which rocks are the oldest and which are the newest is very important. For example, you would expect to find fossils of the







first animals that lived on the earth in the oldest layers of this rock. And that is where they are found. The fossils that you see in the pictures on this page came from some of the oldest rock layers. You see that they are shell animals like those that lived in the water 500 million years ago.

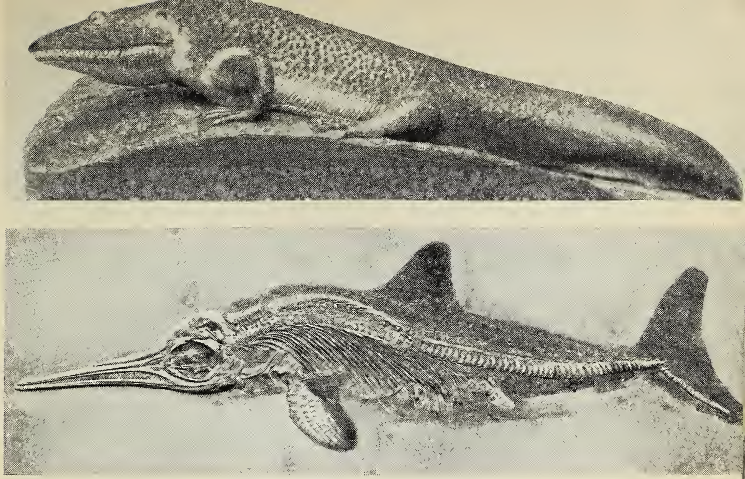
All of the animals found in these oldest rock layers were very simple animals. They had no backbones. Some of them had no hard parts at all; so they did not leave any very clear records. Many of these simple animals kept making more of their own kind year after year and did not change. But some of them changed greatly. Let us see how they changed and became more complex.

This fossil of a fish shows an even more complex animal than the first fish. It not only had a backbone, but had very thick scales and strong fins and tail.

In the next layer above these first rocks, scientists find fossils of the earliest fish. You remember the Saturday trip 350 million years ago when there were so many fish. When scientists compared the fish fossils with the fossils of the earlier animals, they found that a new kind of structure had developed. This new structure was a backbone. The first animals to appear with a backbone were fish. This was a great event in the development of animals. From then on, most of the new animals that appeared had backbones.

You remember that during this very early time there were no land animals. Let us see how the land animals came upon the earth. In the layers of rocks above those that first show fish, we find fossils of more complex animals. These are fossils of the earliest amphibians. Amphibians were the first animals that came out of the water to live on the land.

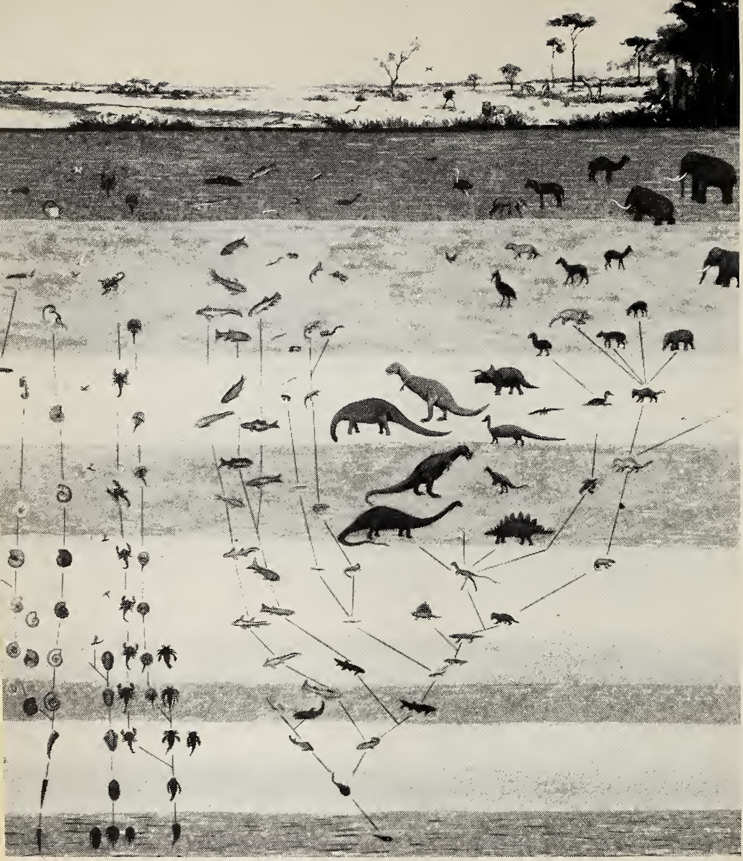
You have probably watched a tadpole develop from a water-living animal into a frog that can live



At the top is a picture of an early amphibian, which shows you how much like fish these animals were. In the lower picture is the fossil of an animal called a fish-reptile because it is partly like a fish and partly like a reptile.

on land. Therefore you can understand how greatly any water animal must have changed before it could have lived on land. Such an animal needed a different way to move about. Fins would not be useful for traveling over the land. Instead of fins, the animal developed legs. Gills would be useless for breathing on land. Lungs were developed to take the place of gills. Many other changes took place in all water animals that began to live on land.

The first animals that developed spent part of their life in water and part of their life on land. These animals, as you know, were the ancestors of our present-day amphibians.



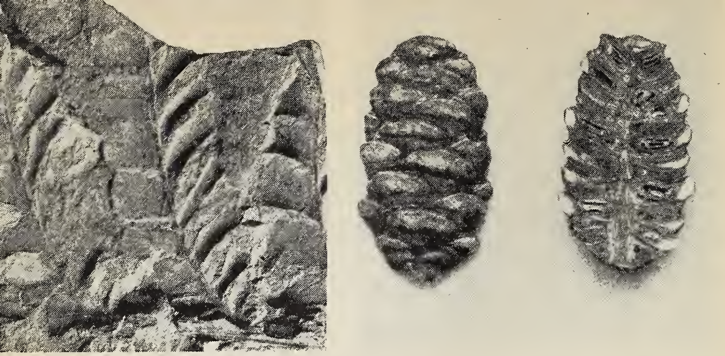
Here is a chart that shows you how scientists think living things developed on the earth. The layers show different layers of rock in the earth. In the bottom layers, or the earliest layers, are the simple animals. As you go upward from one layer to another, you find that the animals are more and more complex. You can see that the animals gradually became more like those we have today.

The fossils in different rock layers show us that after the amphibians had lived on the earth for millions of years the reptiles began to develop. You remember that at one time reptiles were the most important animals on the earth. Scientists believe that reptiles developed from the amphibians. The amphibians lived part of their lives in water and had smooth moist skins. The reptiles that developed had dry scaly skins. They lived almost entirely on land, and their scaly skins kept them from drying out in the hot sun.

Then another new kind of animal developed on the earth. These were the flying reptiles, such as you see in the picture on page 71. Their body parts fitted them to glide through the air from tree to tree. Scientists believe that the first birds developed from some of these reptiles, although they are not sure that birds developed from the flying reptile. The feathers were developed in place of scales. Of course this wonderful change and all the other changes you are reading about took millions of years.

Finally animals with fur began to appear on the earth. They also developed from earlier animals, and they changed until they became like the mammals of today.

When scientists compare fossil animals and plants with today's animals and plants, they find that none of these fossils looks exactly like any living animal or



At the left is part of the print of a giant fern. At the right you see the fossil of a cone somewhat like our pine cones today. One view shows the whole cone and the other shows it split open and the seeds inside.

plant. Careful study of fossils seems to show that the more complex animals developed from the simplest ones. For example, fish with backbones seem to have developed from simple animals without backbones. The amphibians seem to have developed from the fishes, and the reptiles from the amphibians. Birds and mammals also developed from earlier and simpler forms of animals.

The plant fossils that have been found show us that plants, too, have kept changing as they developed on the earth. The earliest plants were very simple, just as the earliest animals were. The first ones were made of just one cell. You would never think that these tiny objects were plants, because they were so small and because they did not have stems, roots, leaves, or flowers.

Mosses and other kinds of plants developed from these tiny one-celled plants. The moss plants were made of many cells, but they did not have stems or flowers. Then the ferns developed, and finally plants with flowers and seeds developed on the earth.

* * *

1. How were the prints formed in the ocean floor, as shown in the picture on page 78?

2. Why do you think that the study of fossils is very important?

3. Name some of the ways in which the animals of the earth are different from each other.

4. How have places like the Grand Canyon of the Colorado River helped scientists learn ways that animals and plants have changed?

5. Explain why the oldest rocks are at the bottom of the canyon. Why is this an important thing to know?

6. Which of these animals is thought to have developed first: one-celled animals, fish, amphibians?

7. Why have scientists called certain periods of the earth's history the *Age of Fishes* and the *Age of Reptiles?*

8. How were the first birds different from the birds that live today?

9. Tell three ways in which plants have changed since they first began to grow on the earth.

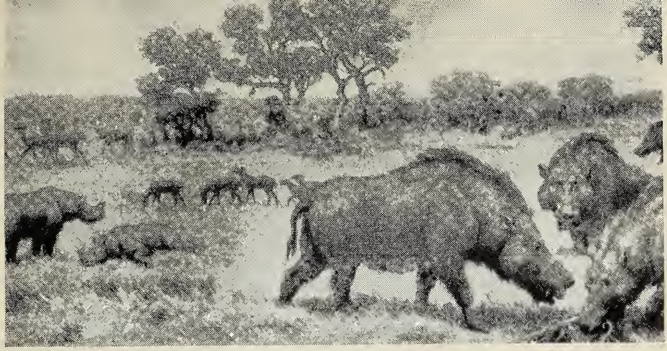
These animals disappeared when their food supply was destroyed. They were probably too large and clumsy to move to new homes.

Why have some kinds of animals disappeared from the earth?

YOU HAVE SEEN how the plants and animals have changed during the millions of years they have been on the earth. During the millions and millions of years the earth itself has changed, too. Some of the great seas that covered the earth have disappeared. In other places the land that had once been low became high, and the water flowed off into lower places to make new seas. The temperature changed also. In some parts of the world where the temperatures had been warm, it slowly became cold. Some of the cold regions changed and became warm.

These changes in the temperature, in the height of the land, and in the water on the earth made it necessary for the living things on the earth to change. They had to change, or they could not stay alive.

There were only three things that could happen



At the right of the picture are ancient animals from which the pigs of today may have developed. In the background you can see small horses and long-necked camels.

to plants and animals when the earth changed. First, the bodies of the animals could change so that they could stay alive in their new kinds of homes. For example, you have seen how some of the animals changed their homes from water homes to land homes. To do this, they needed new structures for breathing and for moving on land. Of course, this took millions of years to happen. They could not exchange fins for legs overnight!

The land animals changed, too. An elephant that lived on the earth millions of years ago was very different from an elephant that you see at a circus today. Camels, buffaloes, bears, zebras, giraffes, and all the other animals have changed. Study the pictures on pages 73 and 77. How have the elephant and the horse changed? The places where these animals lived changed; so their bodies changed, too.

A second thing that animals could do when their homes changed was to travel to another place. For example, if it became cold where the animals were living, they could move to a warmer place. That is, they could *migrate*, as birds and some other animals do today when the seasons change.

But some of the animals did not change, and they did not migrate to new homes. They did the third thing. They died when conditions changed. They did not all die within one year, or within one hundred years. These changes in their surroundings took place very slowly. Most of them took millions of years.

Scientists cannot explain many of the changes in animals and plants. Just how and exactly why these changes took place are hard things to understand. Some time later in your science work you will learn more about the history of the earth and of the living things on the earth.

1. When the surface of any part of the earth changes, some one of three things may happen to the plants and animals living there. What are the three things that may happen?

2. Find two pictures in this unit that show how certain living things have changed.

3. Name three important changes which have taken place on the surface of the earth that made it necessary for animals to change.

This frog has just laid more than a hundred eggs. Think how many frogs there would be if all the eggs laid every spring made new frogs!

Why is the earth not overrun with plants and animals?

ANIMALS and plants have lived on the earth for millions and millions of years, and every year most of them raise young. Did you ever wonder why the earth is not overrun with plants and animals? Every year there are billions and billions of young animals born or hatched on the earth, and there are billions of young plants sprouted from seeds.

In the spring a female frog lays hundreds of eggs. A turtle lays several dozen eggs. Some snakes lay forty eggs or more. Birds lay fewer eggs, but a pair of robins often raises several families each year. Sparrows raise several families each year, too. A codfish lays 9,000,000 eggs a year! Try to find a female spider with her "egg basket" and keep her until the eggs hatch. Then you will see how many young spiders come from the eggs that are laid by one female spider.

These seeds all came from one flower on a thistle plant. There are many flowers like this on one plant; so millions of seeds grow every year.

Plants are also making more of their kind at a great rate. Go into a garden when the seeds are ripening. Select one plant and try to count the number of seeds it makes. And then remember that there are probably hundreds of such plants, each producing seeds, within a very small space.

Does what you have just read make you wonder why the earth does not soon become covered with animals and plants? Of course, you know that most of these animals and plants do not live and grow to be adults. If they did, it would be impossible for you to walk from your home to the school because there would be too many

Some of these trees are growing well, but others seem to be small and spindly. Can you tell why?

plants and animals in your way. Do you know what happens to keep many of these living things from growing up?

As you know, every plant and animal must have certain things in order to stay alive and grow. They need air, food, water, and sunlight. They also need a temperature that is not too hot or too cold, and they need room to grow. Perhaps you think it is a very easy thing for plants and animals to get the things they need to live. But suppose you look about you and examine some plants or animals.

Find a garden where the vegetables and flowers are just coming up. You may find that the plants are crowded close together. They shade each other from the sunlight, and the roots of each plant are taking water and food materials from the neighboring plants. The plants are really carrying on a battle with each other for enough water, sunlight, and food materials. Do you know what finally happens? Some of the plants die before they are full-grown.

Let us see what happens to a group of young tadpoles after they hatch from frogs' eggs in the spring. Many things may happen to them to keep them from becoming frogs. Turtles eat them. Fish eat them. Perhaps the pond where they live slowly dries up. This crowds them into a smaller place. Then there is not enough oxygen and food in the water for them all. In summer the sun may heat the water very hot, or early in the spring the pond may freeze. This will kill many of the tadpoles. From the hundreds of eggs laid by the mother frog, only a few tadpoles ever live to become adult frogs.

This head of a sunflower blossom has over a hundred seeds. You can see that sunflowers make millions of seeds every year. What happens to keep many of them from growing into new plants?

Keeping alive, as you can see, is a difficult thing for plants and animals to do. Only a certain number

Hawks, owls, and weasels eat mice. The number of these animals in a countryside will probably be much the same from year to year if they are not disturbed. But what happens if all the hawks and owls are killed?

of living things can live in a certain amount of space. In the struggle for food, water, and sunlight, the weaker ones die or are killed. Only the strong can last through periods of drouth, flood, and freezing temperatures. As a result, the number of plants and animals which grow into adults is only a small fraction of the plants and animals that start from seeds or eggs. If you watch a pond or some field for several years, you will see that the number of plants and the number of animals remain about the same year after year.

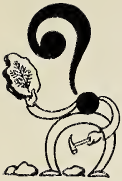
* * *

1. What would probably happen if a frog laid only one egg instead of hundreds of eggs?
2. Why don't all of the seeds of a plant grow into adult plants?
3. Why does the number of plants and animals in a certain place remain about the same year after year?

Questions to Answer

1. Do you think fossils are being formed today? Explain your answer.
2. Why is it important to know about the structure of an animal?
3. In what ways have animals changed since they first came on the earth?
4. Why is a knowledge of the layer formation of sedimentary rock very important to scientists who are studying fossils?
5. Explain why the earth does not become overpopulated with insects.
6. Why do you think conserving our wild animals and plants is important?
7. How can the fossils in rocks be used to find out whether one layer of rock is older than another layer of rock?

Things to Find Out



1. Find out more about the tar pits in California.

2. Try to find fossils in gravel pits and other places near your school. Do these fossils tell what your neighborhood was like at one time?

3. Read about the Petrified Forests in Arizona.

4. Visit a museum to see the fossils.

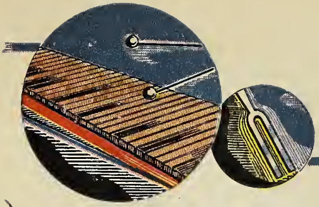
5. Find out how coal was formed.

6. Make a frieze for your classroom showing the different animal ages millions of years ago.

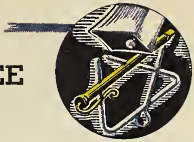
7. Make a model in clay of one of the ancient animals shown in this unit.

8. Go to a hill or a place where a railroad has cut through a hill. See how many layers of different kinds of rock you can find.

9. Find out what kinds of rock are found in your neighborhood. What does this information tell you about the ancient history of your locality?



UNIT THREE



WHAT MAKES SOUND?

How are sounds made?

ONE DAY a teacher said to her science class: "When you come tomorrow, bring something that will make a sound. Then we will experiment with the things you bring to find out how each one makes a sound. I wonder how many different kinds of sound-makers you can bring."

The next day the boys and girls brought many sound-makers. Then they began to experiment with each one to discover how it made a sound.

Billy's sound-maker was a very simple one. He took his ruler and laid it flat on his desk so that half of it reached beyond the desk. He held the ruler firmly on the desk with one hand and with the other hand pulled down hard on the end that stuck out. Then he let go. "Buzz-z-z-z" went the loose end of the ruler. The pupils looked closely to see what made the sound. But they could only see that the end of the ruler was moving up and down swiftly.

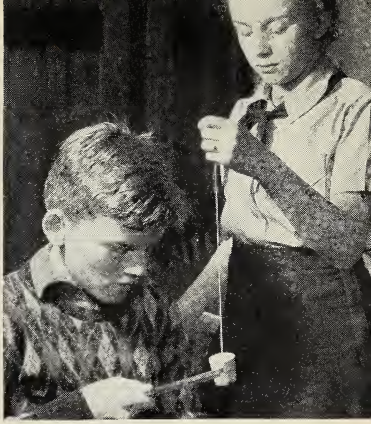
Sally and Alice made a sound by using a rubber band. Alice stretched the rubber band, and Sally snapped it with the end of her finger. "Zing-g-g" went the rubber band. Everyone could see that the rubber was moving rapidly back and forth.

Fred brought the triangle that he used in the school orchestra. He held it up by a string and struck it with a piece of iron. The triangle made a ringing sound. When he touched the triangle with his hand, it stopped ringing. Fred said that it tickled his hand when he touched it.

The teacher held up a tuning-fork and said, "Who can make a sound with this?" George said he could, and he struck one of the prongs of the tuning-fork against a piece of wood. Then he held the tuning-fork near the ears of some of the children. They could plainly hear the singing sound that came from it, but they could not see what made the sound.

Then the teacher asked them to do an experiment and to watch closely and think, to see what the experiment showed. Try this experiment yourself and see what you can learn. Strike the prongs of a tuning-fork and quickly hold the fork so that the ends of the prongs just touch some water in a pan. What makes the water spatter? What does this show you about the prongs of the fork? If you have a triangle, try the same experiment with it. The boys and girls decided that when anything made a sound, it moved rapidly back and forth.

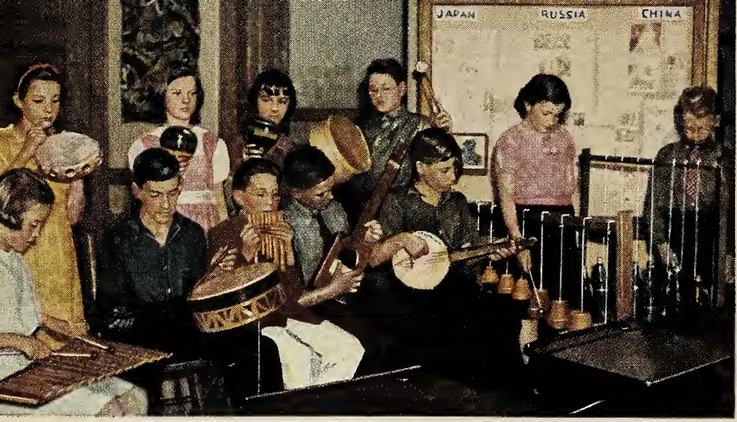
Now try another experiment to see whether this is true. Tie a small piece of cork to a long thread and



hang it up where it can swing without touching anything. After striking the tuning-fork, let one prong very gently touch the cork. What happens? What made the cork move? This showed that the tuning-fork was moving rapidly as it was making a sound.

We say that anything which moves back and forth rapidly is *vibrating*. The prongs of the tuning-fork were vibrating; so was the rubber band, and so were the ruler and the triangle. Each of these things makes a sound when it is vibrating. When the vibrating stops, the sound stops. If you touch the rubber band while it is vibrating, you will find that the vibrating stops, and that the sound stops, too.

What do all of these experiments show you about sound? They show that sound is made by vibration. The rubber band, the triangle, the tuning-fork, and the ruler make sounds only when they are vibrating. The honk from an automobile horn is made by vibra-



The boys and girls in this orchestra made their own instruments. Can you tell what makes the sound of each one?

tions. The voices of your teacher and of your classmates and the ringing of the bells that you hear in your school-room are made by vibrations.

* * *

1. How can you stop the sound of a triangle or a tuning-fork? Why can you stop it this way?
2. In what way are all things alike that are making sounds?
3. Make a list of some different kinds of sounds that you have heard today. For as many of these sounds as you can, tell what was vibrating to make the sound.
4. Find things that will make sounds and see if you can find the vibrating parts.

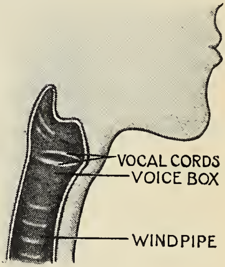
How do living things make sound?

If you stand quietly in a woods or in a farmyard, you will hear many sounds made by living things. Birds sing, frogs croak, dogs bark, insects buzz, pigs squeal, and cats mew. When you try to tell someone about these sounds, then you, too, are making a sound. But how do living things make sounds? Do you know?

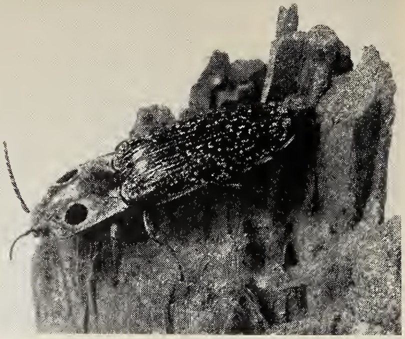
Suppose you hum a tune, and while you are humming, feel your throat. Hold your throat tightly enough to feel the quiver. This, of course, tells you that there is something inside your throat that is vibrating when you hum.

Inside your throat there is a sound box. From it come all of the sounds that you make when you talk, sing, hum, or shout. Inside this sound box, or voice box as it is sometimes called, there are two parts called *vocal cords*. They are somewhat like rubber bands, and they make sounds in much the same way.

Of course, there is nothing in your throat to pick the vocal cords to make them vibrate. Air makes your vocal cords vibrate. The air from your lungs strikes the cords and makes them move



Your vocal cords are in a "voice box" at the top of your windpipe.

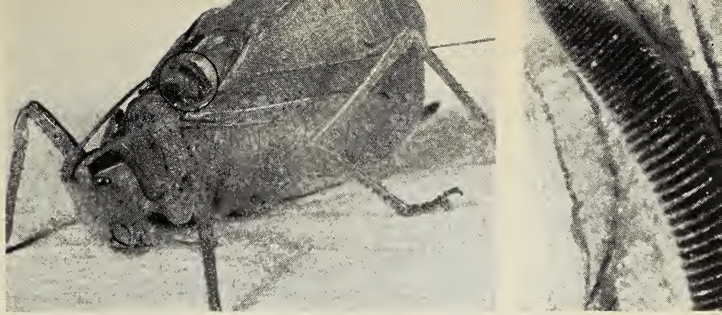


In the picture at the right is a "click" beetle. It clicks by rubbing the hard covering of its head against that of its body. The tiny peeper frog makes a shrill "peep" that can be heard for a long distance. He puffs out his throat and makes both the air sac and the air inside it vibrate.

back and forth. They vibrate as a blade of grass vibrates when you hold it between your thumbs and blow on it. Perhaps you can find blades of grass and show how moving air causes them to vibrate and make sound. Or try blowing on pieces of cellophane or paper. You will need to hold the paper tightly between your thumbs.

Have you ever watched a bird's throat as it sings? Did you see its little throat quiver? If you have, then you know that something inside a bird's throat vibrates, too. Birds have vocal cords. These cords vibrate and make sounds when air from the bird's lungs passes over them.

Insects have no vocal cords. But they have other ways of making sounds. Some of them are drummers, and some are fiddlers. One kind of beetle that lives



The circle in the first picture marks the sound file on the cricket's wing. In the second picture the file has been enlarged so that you can see the ridges in it. When the cricket rubs the other wing across this file, it makes the wings vibrate, and you hear the sound of the cricket.

in old wood strikes its head against the wood and makes a sound somewhat like the beat of a drum.

The katydid and the cricket have a fiddle and a bow! The male is the musician of the family. Part of one of its wings is rough like a file. Part of the edge of the other wing sticks out. When the katydid rubs its wings together, it makes a noise that sounds like this: "Katy did—katy did—katy did," or "She didn't—she didn't—she didn't." The cricket has a cheerful chirp, chirp, chirp.

The fly and the bee make their humming noises by moving their wings up and down very rapidly. The humming-bird also makes its humming sound by the rapid vibration of its wings.

Living things often use their sounds to warn each other of danger. Have you ever heard a mother bird send out sharp cries of warning to her young when a cat comes near her nest? Birds may use their voices to call to each other. No one knows just how much wild animals can say to each other. That is a question that scientists find very hard to answer.

Human beings can make their sounds form words. None of the other animals can do this. When you wish to ask a question of someone, your vocal cords vibrate. Your teeth, lips, and tongue help you to form sounds that make words. Your brain helps you say what you wish, and then your friends can understand you.

* * *

1. Which of these sentences tells how your vocal cords make sound?
a) Vocal cords are in the throat.
b) The voice-box is small.
c) The vocal cords vibrate.

2. What makes vocal cords vibrate?

3. Get some grasshoppers, crickets, katydids, or other sound-making insects and see if you can find how they make sound.

4. Try making different sounds such as ā, ō, ū, ē, and ī. As you make each sound, see if you can tell any difference in the way you hold your lips and tongue. Write a set of directions explaining how to make these sounds.

How does sound travel?

You know that when you speak, something must take the sound from your vocal cords to the ears of your friends. When you hear sounds around you, these sounds must be carried to your ears. How does sound from vibrating objects get to your ears? The sound travels through the air. It travels in waves called *sound waves.*

You cannot see these waves or vibrations in the air, but you can do an experiment to show that the vibrations are traveling through the air. Use two tuning-forks that are alike. Set one tuning-fork vibrating and then hold the other fork very close to it. Do not let the two forks touch each other. What happens? Why does the second tuning-fork vibrate?

The girl can feel the tom-tom vibrate as the boy beats his drum.

Something had to start the forks vibrating. The first fork vibrated because you struck it. The other fork began to vibrate because the vibrations from the first one traveled through the air to it. Did you see them travel? Try the experiment again and watch closely. Of course you cannot see the sound waves. But your experiment proved that the sound waves traveled through the air, even though you could not see them. Every vibrating body sends vibrations, or sound waves, into the air. They travel out in every direction from the material that is vibrating.

You can show that sound travels in every direction if you do this experiment. Have someone ring a bell. Walk around the bell as it is ringing. Can you hear it wherever you are? How does this show that sound travels in every direction?

If sound waves did not travel through air, it would be impossible for you to hear anything. When people talk to you, the sound waves that are started by their vocal cords travel through the air to your ear. When a whistle blows, these sound waves come to your ear through the air. The sound of music, of birds, and of thunder, and all the other sounds that you hear, come to you through air. If you could take all the air out of a room, you would not be able to hear a sound in that room.

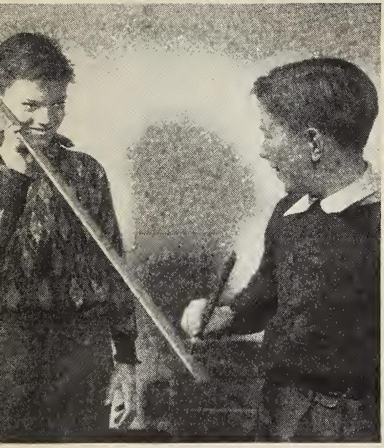
But is air the only material that sound will travel through? Perhaps you can answer that question by reading about Jerry and Bob. Jerry and Bob were swimming. While Jerry was diving, Bob was gathering stones and piling them on shore.

Once, just as Jerry dived, Bob cracked two of the stones together under the water. As Jerry climbed out on the bank, he said, "Say, Bob, what made that loud sound in my ear when I was under water?" What does this tell you about sound?

Henry's father always wakened him in the morning. He could tell Henry that it was time to get out of bed without saying a word. When Henry's father went to the basement to put coal in the furnace, he tapped three times with the furnace shaker on an iron heating pipe. This pipe went up to the radiator in Henry's room, and the radiator was close to Henry's bed. Then Henry tapped three times on the radiator to let his father know that he had heard the message.

Did the story about Jerry and Bob tell you that water carries sound? Did the story about Henry tell you that iron carries sound?

You can do some experiments that will tell you more about how sound travels. Use a yardstick



and a tuning-fork. Hold one end of the yardstick close to your ear and straight out from it. Have someone strike the tuning-fork gently to make it vibrate and then hold the handle of it against the other end of the yardstick. Can you hear the sound from the fork as it travels along the solid stick? Now let someone strike the tuning-fork gently and hold it a yard away from your ear without the yardstick. Can you hear the sound now? What does this show you about a solid and a gas as carriers of sound?

Repeat the experiment, but use a strip of cloth and a tuning-fork. Hold the cloth out straight, as you did the yardstick. Does the sound travel easily along the cloth? Soft materials like cloth do not carry sounds so well as wood and other hard, solid things.

You remember that there are three kinds of materials in the world. They are solids, liquids, and gases. All three of these can carry sound. Air is a gas. Water is a liquid, and iron is a solid. Gases do not carry sound as well as liquids and solids do. Liquids are better carriers than gases. But solids are the best carriers of sound. Now can you tell why you can hear the sound of a train far down the track by putting your ear to the rails? Do you know why Indians put their ears to the ground to tell when horses were approaching?

Sound travels very fast. When it is speeding through air, it travels about 1100 feet in one second. It takes sound only about five seconds to travel a mile. Sound travels faster than this through wood, water, and metals. A high sound, a low one, a loud sound, and a soft one, all travel at the same speed. Of course, a soft sound does not travel so far as a loud one.

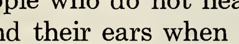
You remember that sound waves travel out in every direction from a vibrating object. Sometimes we may want to make the sound waves go only in one direction. So we try to guide the sound waves. Here is a picture of a cheer leader using a megaphone to direct his voice to the crowd. When you wish to call to a friend who is some distance away, you cup your hands around your mouth. This helps to

guide the sound waves in the direction in which you wish them to go.

Suppose you make a megaphone out of cardboard and then try this experiment. Have someone in your class stand in one corner of your room and speak very softly without using the megaphone. Then let this pupil use the megaphone, still speaking very softly. Can you notice the difference? Do you see how the cardboard helps to guide the voice to you? Repeat this experiment, using a watch. Listen to the watch with the use of the megaphone and then without it. Can you notice the difference?

The people in the picture on this page are noticing something interesting about sound. When they were talking, their voices "came back" to them. The walls of the canyon *echoed* their voices. Have you ever called to a friend and heard your voice come back to you? This sometimes happens when you are between tall buildings, among hills, or in a large, empty room. The reason for the echo is that the sound waves of your voice travel through the air, strike a surface, and are then reflected. You remember that *reflect* means to throw back. When the sound waves from your voice are reflected, they travel back through the air, and you hear them again. This is the echo.

Sometimes you can hear many echoes of the same sound. In this case the sound waves bounce back and forth between the reflecting surfaces.



1. About how long will it take the sound of a cannon to travel three miles?

2. Why do people who do not hear well often put their hands behind their ears when someone is talking to them?

3. Which of these sentences tells something that is not true?

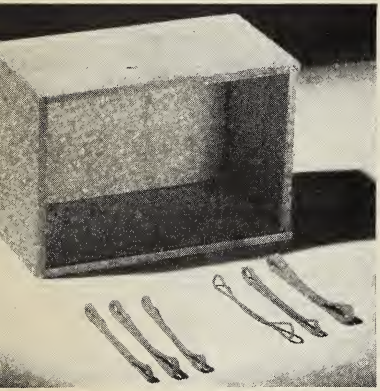
a) Sound travels only in the air.
b) Sound travels about 1100 feet in one second.
c) Sound waves travel in all directions from a vibrating body.

4. Which of these materials carries sound best: air, water, iron?

What makes the differences in sounds?

If you have heard an orchestra tune up before it begins to play, you know how sounds differ from each other. Someone picks a violin string and listens to the sound. Then he tightens or loosens the string, picks it again, and gets another sound. At the same time someone else is blowing the flute. It makes a very different sound.

Now the drum sounds a "boom boom," and the cornet pipes out with a shrill "toot." The bass fiddler draws the bow over the strings of his instrument, and they vibrate to make a low sound. All of this is happening at once, because each player is trying to get his instrument in tune. When the orchestra plays, you hear many sounds. The piccolo and violin make high sounds. The drum and the bass fiddle make low sounds.



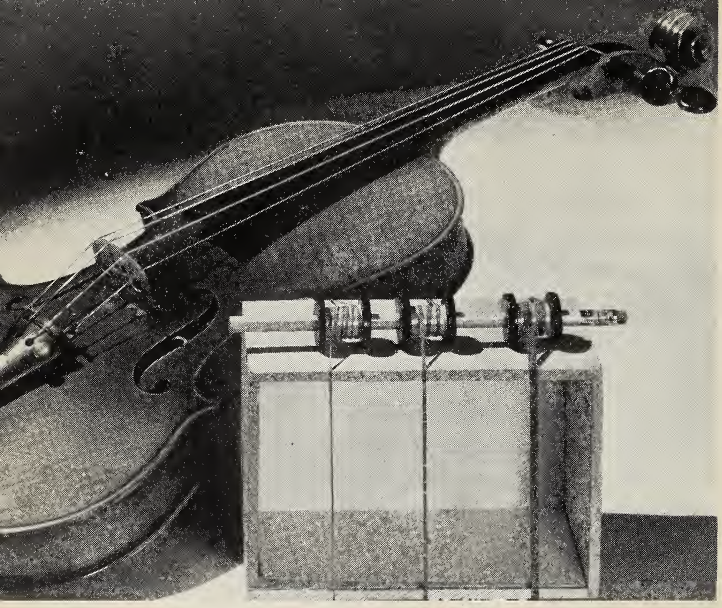
Read page 125. Then tell two things about sound that you can prove by using these materials.

Can you find out why some of these sounds are high and others are low? Here is an experiment that will help you. You will need a chalk box and three rubber bands of different widths but the same length. Stretch the rubber bands across the open side of the box. Try to make them all equally tight. Pluck them as you would pluck the strings of a violin or a banjo. Do they all make the same sound? Listen carefully to the widest band; then listen to the narrowest one. Which one makes the highest sound? Which one makes the lowest sound? Which one seems to vibrate most rapidly? You have found that the widest band makes the lowest sound and that the narrowest band makes the highest sound.

If you looked closely at the vibrating rubber bands, you saw that one of them was vibrating faster than the other two. The one that was moving fastest made the highest sound. The one that vibrated the slowest made the lowest sound. When anything vibrates fast, it makes a high sound. The wide, heavy band did not vibrate so fast as the narrower bands.

Have you ever noticed the strings on a violin, a harp, a guitar, or a cello? The thickest strings make the lowest sounds, and the thinnest strings make the highest sounds. Perhaps you can get a toy xylophone and bring it to school. Which bars make the high tones when you strike them? Which make the low tones? The long bars are like the thick strings on a harp. They make low tones because they cannot vibrate so rapidly.

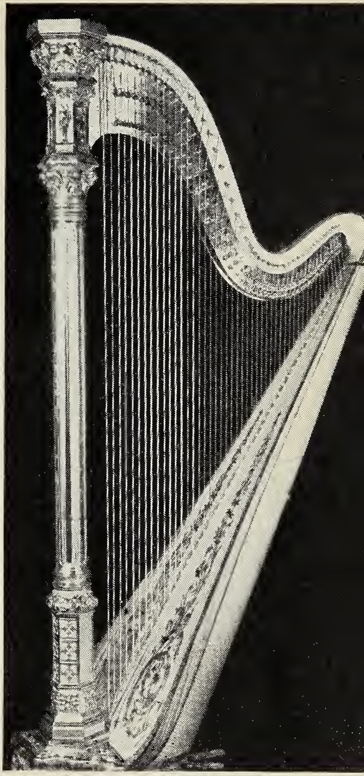
Now try another experiment with rubber bands,



You can use a box with rubber bands of different widths to show why the strings of a violin make different sounds. Which band would you stretch the tightest to make the highest sound? Why?

but this time use three bands that are alike in length and width. Stretch them across the chalk box, but stretch the second band tighter than the first and the third tighter than the second. Pluck them with your finger. Which makes the highest sound? Why does it make the highest sound? When strings are stretched tight, they can vibrate more rapidly. Therefore, tightly stretched strings make high sounds.

Each string in the harp can be tightened to make a higher sound or loosened to make a lower sound.



And each string makes a different sound from all the others. Study the picture and see if you can find two reasons for this. One reason, of course, is that some strings are very thin and fine and others are thick and heavy. Can you find another difference in the strings? You see that some are longer than others. Which ones are longest, the thick strings or the thin ones? Notice that the thickest string is the longest of all, and the thinnest string is the shortest. A short string vibrates faster than a long string. So you can see that this short, thin string will vibrate very much faster than the long, thick string on the other side of the harp. Therefore, the short string will make a much higher sound than the long one.

You have learned that high sounds are made if the vibrating material is moving very fast. Low sounds are made if the material that is vibrating is moving slowly.

If you understand this, you can answer these questions: To make a high sound, would you use a thick string or a thin one? Would you make the string long or short? Would you stretch it tightly or loosely?

The bars in this xylophone make different sounds. Can you tell why?

Sounds are different in another way besides being high and low. They may be loud or soft. Some sounds are so soft that we can hardly hear them. Others are so loud that they hurt our ears. Listen to the two sounds as you strike a bar on the xylophone lightly and then hit it hard. You heard the same tone both times, but did it sound louder when the bar was hit hard? When you play the same key on the piano softly and then loud, it gives the same tone. Each piano wire gives its own sound, but the sound is louder when the wire is hit hard. Let us try a few experiments to find why some sounds are louder than others.

Suppose you try the experiment with the ruler on page 109 in two ways. First, pull the ruler down just a little way and let it go. Notice how far it moves up and down. Then pull the ruler far down and let it go. Watch it. Did you see that it moved much farther up and down the second time?

Try the experiment with the tuning-fork and the cork on page 111 in two ways. First, strike the tuning-fork lightly and hold it beside the cork. How far was the cork moved by the vibrations of the tuning-fork? Then strike the tuning-fork hard and touch the cork with it. This time was the cork moved farther? This shows that the tuning-fork pushed the cork with more force.

The farther anything moves as it vibrates, the harder it pushes the air, and the louder the sound.

You have found what makes sounds high and low and loud and soft. You can make your voice change from high to low and from loud to soft. Do you know why you can change the sound of your own voice? You remember that there are two vocal cords in your throat, which vibrate and make the sound you wish. Between them there is an opening. When you are not using your voice, these vocal cords are wide apart and loose. The air goes past them without making any sound.

When you talk, you make the muscles in your voice-box stretch the vocal cords. When they are stretched tightly, they are drawn closer together.

The air from your lungs strikes this narrow slit between the tightly stretched cords, and you make a high sound. When the muscles do not stretch the vocal cords so tightly, they make a lower sound. You change the tightness of your vocal cords many times every minute when you talk.

As boys grow up to be men, their voices usually change from high to low. This happens because the vocal cords change. You remember that a thick rubber band makes a lower sound than a thin band does. Girls and women have thinner vocal cords; so their voices are higher.

1. Some of the strings on a harp make low sounds; others make high sounds. Which of the following sentences explain the reason for this?
a) Some are longer than others.
b) Some are thicker than others.
c) Some are stretched more tightly than others.
d) Some do not carry sound well.

2. How is the sound of a train whistle different from that of a fog-horn?

3. Name two ways of making the sound of a rubber band higher.

4. Find an old mouth-organ, or harmonica. Take off the outside cover and play it. Which parts make the high sounds and which make the low sounds?

How do musical instruments make sounds?

ON THIS page is a picture of the Greene County School orchestra. Can you name the instruments the boys and girls are playing? When these pupils were learning about sound, they brought some of their musical instruments to their science classes. They brought a violin, a cello, a drum, a xylophone, a flute, a trombone, and a saxophone. Each pupil showed how his musical instrument made sound.

What do you already know about these instruments? You know that the sounds they make are caused by vibrations. You also know that they can make sounds that are loud, soft, high, or low.

On the left Jack is showing how he can shorten the strings by "stopping" them with his fingers. On the right he is showing how he tightens the strings. What happens to the sound when he does these two things?

Here is a picture of Jack telling the class about his violin. "My violin has four strings," he said. "You can see that they are not all alike. Some of them are thicker than others. Of course the thick ones make the low sounds, and the thin ones make the high sounds." Jack plucked the strings to show the different sounds.

Then Jack said, "If I want to make the sound higher, I shorten the string. I put my finger on part of the string so that some of it won't vibrate. The part of the string that I press is touching the violin, so that it can't vibrate. The shorter I make the string, the higher the sound it makes. I can make the sound higher in another way, too. I can stretch the string tighter with these pegs at the top."

Jack showed his classmates how tightening the string made the sound get higher and higher. When he let the string get looser and looser, it made a very low buzz. After Jack had tuned his violin, he drew his bow across the strings to make them vibrate. Then he used the bow and his fingers on the strings to play a tune.

Have you ever seen the inside of a piano? Each key on the piano is fastened to a little hammer. When you strike the key, the hammer strikes a wire and makes it vibrate. Some of the wires are long and thick; others are short and thin. If the hammer strikes the longest, thickest wire, would it make a low note or a high note?

Strike the last key at the left end of the piano. This sound comes from the longest, thickest wire. How is it different from the sound you make when you strike the last key at the right end of the keyboard? Probably you have heard a piano-tuner at work as he tightens and loosens the wires to make the sounds a little higher or lower.

John plays the xylophone in the school orchestra. He makes the different sounds by striking wooden bars with wooden hammers. The bars are of many

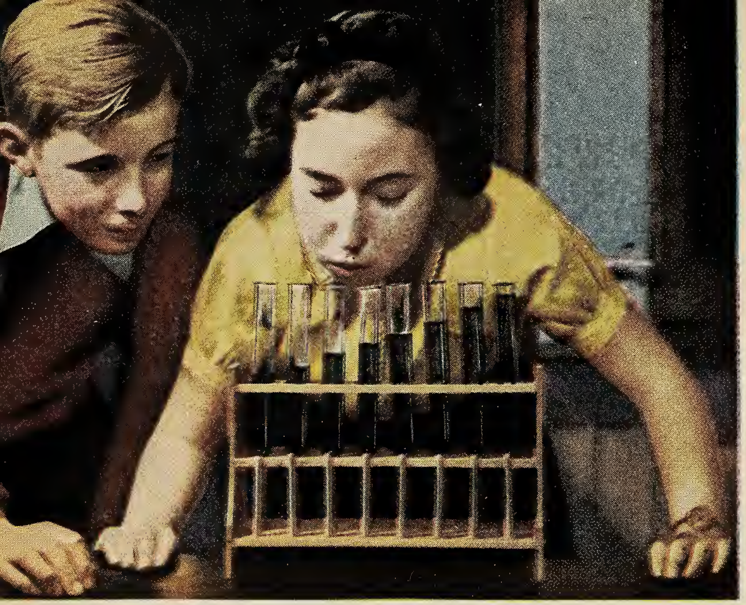
different sizes. Some are long; some are short. The bars are not fastened tightly. Can you tell why bells, chimes, cymbals, triangles, and drums all make sounds when they are struck? Each of these instruments gives its own kind of tone.

Here is a picture of Paul with his flute. You see that the flute does not have strings, and of course you do not strike it with a hammer to make it sound. The flute is a long, slender tube with holes along the side. Paul makes the sound by blowing across the hole near one end of the flute. This makes the air in the tube vibrate. Paul can make high and low tones on the flute by placing his fingers over holes in the sides. When he does this, he changes the length of the column of air in the tube. When the column is shorter, the sound is higher. Paul makes low sounds by putting his fingers over all the holes. This makes the column of air longer. Then when Paul blows, the sound is low.

Joe plays the saxophone in the orchestra. He explained how part of the saxophone vibrates when he plays. The vibrating part is called a *reed*. Notice the reed in the picture. Joe has taken the mouthpiece off his saxophone and has taken the reed out of the mouthpiece to show it to his classmates.

"This reed vibrates when I blow on it," he said. "I can feel it quiver. The vibrating reed makes the column of air in the saxophone vibrate too. I can change the sound from high to low or from low to high by changing the length of the column of air. I push down and let up on these *valves* to change the length of the column of air." Can you see the valves on the saxophone in the picture?

The following experiment will help you understand how long and short columns of air make



different sounds. Do the experiment carefully, and you may be able to play a tune. Take eight test-tubes and fill them with different amounts of water as shown in the picture. You may use small bottles that are alike in size and shape if you cannot find test-tubes. Blow gently over the top of each tube. Do they make different sounds? Which one makes the lowest sound? Which one makes the highest?

You see that the test-tubes in the picture do not all have the same amounts of air in them. The one on the left end has the longest air column. The one on the right end has the shortest air column. A long column of air makes a low sound. A short column of air makes a high sound. Blow across each tube and see how the sounds get higher as you go toward the one with the shortest air column. Now you can understand how Paul's flute works. He can make the air column longer or shorter by placing his fingers over the holes in the flute. Joe makes the air column in his saxophone long or short by pressing the valves of the saxophone.

There are several other instruments in the orchestra that use columns of air to make sounds. The trombone player makes the column of air in his horn shorter or longer when he slides part of the horn back and forth. The tuba and the cornet are other instruments that make different sounds because the length of the columns of air can be changed. The tuba and the cornet have valves that make the air column shorter or longer.

In what two ways can this trombone player change the sounds the trombone makes?

But you cannot play a trombone, bugle, or trumpet by just blowing through it. You have to do something to make the air column vibrate. Did you ever try to play a bugle or a trumpet? You quickly found that you must hold your lips just right to make a sound. You hold them tightly against the mouthpiece, and you press them together. Then, when the air comes through them, they vibrate. Your vibrating lips make the air in the horn vibrate; this makes the sounds. By holding your lips tightly or loosely, you change the way in which they vibrate. Then the air in the horn vibrates differently, and you make different sounds when you blow.

* * *

1. Name five musical instruments that make sounds because their strings vibrate.
2. Why do some keys on a piano make low sounds and others make high sounds?
3. What three important things did Jack know that helped him explain to the class why his violin made different sounds?
4. Could John have played a tune on his xylophone if the bars had been all the same length and thickness? Why?
5. In what two ways can a trumpet player make different sounds on his trumpet?
6. Could you play a saxophone in which there was no reed? Why?

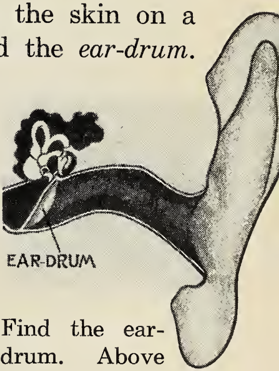
How do we hear sounds?

Some of the sound waves made by vocal cords, whistles, musical instruments, street-cars, and other things are caught by your ears. Part of your ear is inside your head, and part of it is outside. The outside part of your ear is shaped so that it acts like a funnel to catch the sound waves. Have you ever noticed how dogs or rabbits sometimes hold their ears up so that they will catch sound waves better? Cup your hand and hold it behind your ear. Do you see how this helps to catch sound waves?

At the end of the opening that goes to the inside part of your ear there is a very delicate, thin skin. It is stretched across the opening like the skin on a drum. This skin in the ear is called the *ear-drum.*

Now let us see what happens when we hear the sound from a tuning-fork. You know that the sound waves travel through the air to your ear. The outside part of your ear catches these sound waves, and they strike the ear-drum and make it vibrate. These sound waves make your ear-drum vibrate just as fast or as slowly as the tuning-fork vibrates.

Above the ear-drum there are some tiny bones joined together.

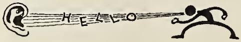


Find the ear-drum. Above the drum are the tiny bones that vibrate when the ear-drum is vibrating.

The end of one of them is fastened to the ear-drum. Every time the ear-drum vibrates, these bones move. They vibrate just as the ear-drum vibrates.

Do you see that the vibrations of the tuning-fork have traveled to the bones inside your ear? From these vibrations a nerve in your ear gets a message of sound and carries it to the brain. Then you hear the sound of the tuning-fork. The inside parts of your ear all work together with your brain so that you can hear the sounds and know what they mean.

It is interesting to notice that you can tell from which direction a sound is coming. Have three or four boys and girls stand in different parts of the room and make some sounds. The rest of you close your eyes and listen. Can you tell from what part of the room the sounds are coming? Even though you do not see what is making the sound, you can often tell what is making it. Your ears and your brain work together to help you tell what kind of sound you are hearing and where the sound is coming from.



1. Why does the shape of the outside part of your ear help you hear sounds?
2. Tell why *ear-drum* is a good name for that part of your ear.

3. Why do you think it is dangerous to put things in your ear?

4. What do you think a sudden, very loud noise might do to your ear-drum?

5. Soldiers shooting big cannons usually put cotton in their ears. Why do they do this?

6. If you could not hear clearly what people said to you, which of the following would you do? Give a reason for your answer.

a) Ask people to speak louder.
b) Go nearer to the person who is speaking.
c) Ask a doctor to examine your ears.

Questions to Answer

1. Can sound travel around corners? Plan an experiment to prove your answer.

2. Why do we not hear a sound except when something is vibrating?

3. Bob put his radio on a table that had a metal top. Whenever he played the radio, there was a harsh "twang" that spoiled the music. Soon Bob discovered that it was coming from the metal table top. Can you tell what caused the table top to make the sound? What could Bob do to stop it?

4. If you drive a pin into a block of wood and pluck it with another pin, it will make a sound. How could you drive eight pins into the block so that they will make different sounds and play a tune?

5. Why does a bell make the same tone every time you strike it?

6. Why are these good rules for taking care of your ears?

a) Never put anything sharp or pointed in your ear.
b) Never put your fingers in your ears.
c) Never let anyone blow in your ears.

Things to Find Out

1. Bring sound-making toys to school and find out how they make sounds. Bring whistles, horns, musical tops, and whistling balloons. Perhaps you can make some musical toys.

2. Find out what makes the sound in a pipe-organ. Which pipes make the high tones and which make the low tones?

3. Find out how a speaking tube works in an apartment house.

4. Study the insects and other animals that you see around you and find out how each one makes its own sound.

5. Make some good rules for taking care of your ears.

6. Find out what is done to stop echoes in public auditoriums.

7. Make a "box harp" by stretching rubber bands of different widths across the open side of a cigar box. Stretch some of the bands tighter than others.

8. Make a xylophone by cutting small pieces of wood into different lengths and fastening them loosely on two longer pieces of wood. Make small hammers out of wood to use in playing the xylophone.

9. Make "flower-pot chimes" by putting small ropes through the holes in the bottoms of four different-sized flower-pots. Knot the rope inside the flower-pots and hang each one separately. Strike them with a wood hammer.

10. Play a "Sound Game." Have two or three boys and girls assemble many different "sound-makers" behind a screen. Let the rest of the class try to tell what is making each sound.

11. Make "musical glasses" by filling drinking-glasses with different quantities of water. Use six or eight glasses and completely fill the first with water and leave the last one empty. You can play the musical glasses by striking them with a spoon.

12. Make whistles and flutes out of dried weed stems, corn stalks, or willow branches.

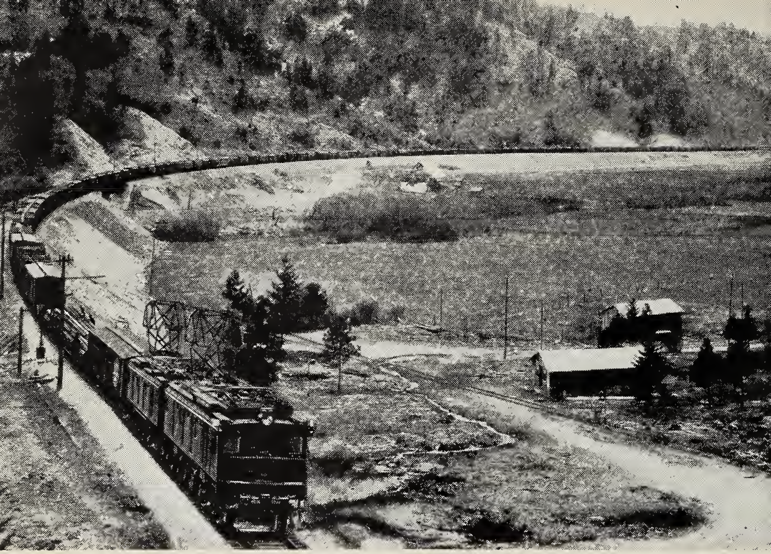
13. Make a toy telephone by using two tin cans and several yards of string. Punch a hole in the bottom of each can. Then pull one end of the string through the hole and tie a knot in it or tie a button on it so that the string will not slip through.

UNIT FOUR

HOW DO WE USE ELECTRICITY?

ONE STORMY night in the mountains great masses of rock and soil, loosened by heavy rains, began to slide down into the valley. In their pathway were some tall poles that supported copper wires. The wires were used to carry electricity from a power-house in the mountains to a city in the valley below. When the rock and soil struck the poles, the poles were broken off like match-sticks, and the wires were snapped as if they had been thread. Immediately the city was in darkness. A moment before, brilliant electric signs had flashed above lighted store windows, but now both signs and stores were dark. So were the streets and homes.

Of course, some electricity was still being used. Flash-light batteries supplied enough electricity to make some light. Automobile batteries made enough electricity to start the cars and to light the head-lamps. In a hospital a surgeon was performing an operation when the lights went out. He had to finish the operation by the light of flash-lights. But everything that used electricity from the town's electric power-house up in the mountains had stopped.



Here you see an example of the huge load that electricity can move. Two electric locomotives are pulling a train of 107 cars with 7000 tons of freight in them.

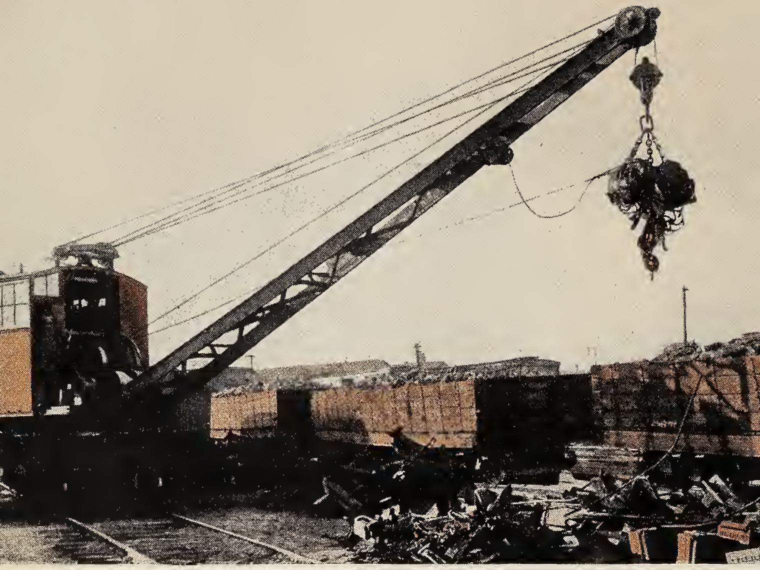
In the theaters there was no electricity to run the moving-picture machines and no light to throw the picture on the screen. The street-cars no longer ran, because the force that moved them was gone. In the newspaper office the printing-presses and the type-setting machines were stopped; so the newspaper could not be printed. A dentist could not go on filling a patient's tooth, because there was no electric power to run his drill.

Out in the country were farmers who had electric pumps that brought water up from deep wells into their houses and barns. Now there was no power to run the pumps. In almost every home and building in the town and on farms near the town there were tools and appliances that would not work because the electricity was "off." You can see why it is a serious thing for people when electricity "goes off."

Have you ever thought of the many things that electricity does for you? You push a button, and electricity lights the room. If you are cold, an electric heater will warm you, or if you are too warm, an electric fan will cool you. An electric stove will cook your food, and an electric toaster will toast your bread. An electric washing machine will wash clothes; an electric iron will iron them; and a vacuum-cleaner will clean your carpets. In this unit you will learn many things that will help you understand how electricity works to do such useful things for you every day.

How can you use electricity to make a magnet?

WHAT DO you know about this helper that comes so quickly and quietly to your aid when you press a button? Not so long ago people knew almost nothing about it. When our country was fighting its war for independence, not a single useful thing was known about electricity! It is true that thousands of years ago people noticed certain kinds of electricity. They saw lightning in the sky during a storm, and



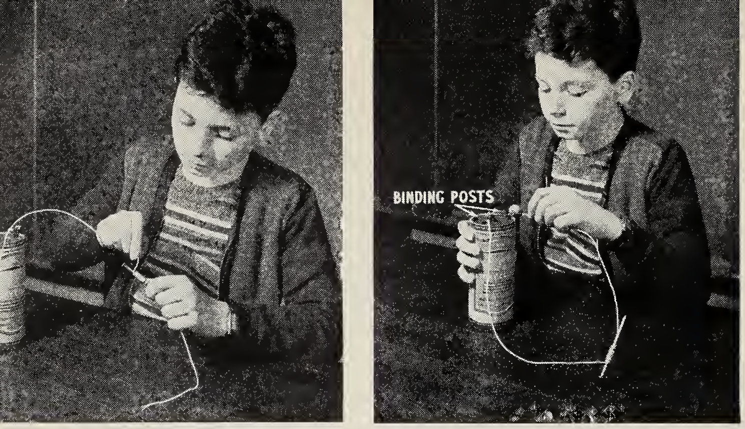
Benjamin Franklin proved that lightning and electricity are the same thing. But people could not use the force of the electricity in lightning, and we cannot use it today.

Before men could make electricity help them, they had to learn much more about it than those people of long ago knew. What are some of the things they learned? To answer this question, suppose you begin by thinking about things you may have seen.

Did you ever see a crane like the one in the picture on this page? You will often find such cranes being used in railroad yards, steel mills, junk yards, and other places where iron and steel are loaded and unloaded. If you watch one of these cranes at work, you see it swing out over a pile of iron. The big, flat, circular object hanging from the end of the long arm is lowered until it touches the pile of iron. When this big circular part is lifted, tons of iron are clinging to it. The iron sticks as if glued, yet nothing seems to be holding it. Then the crane swings around until the circular object with the load of iron is over a railroad car. Suddenly the iron drops into the car. Again and again the crane swings from the pile of iron to the car and back to the pile. Each time it picks up a load of iron, carries it to the car, and leaves it.

Of course a man is making the crane work. He can swing the crane around to wherever he wants it. Do you know what he does to make the iron stick to the big circular object? Since the iron is not fastened to the circular object, you may be sure that some kind of force is holding it to this object. But what is this force? And what does the man do when he wants to drop the iron? You can discover the answer to these questions if you do this experiment.

Get a large nail or bolt, a saucer of tacks, an electric dry cell, and about two feet of copper wire covered with cotton or silk. First dip the large nail into the saucer of tacks. Do any of the tacks stick to the nail? If the nail were a magnet, the tacks would stick to it. If the nail does not attract the

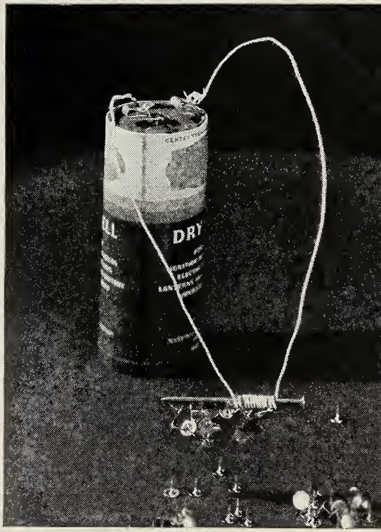


Jim winds the covered wire around the nail and connects each end of the wire to a binding post on the dry cell. What happens to the nail?

tacks, you know that it is not a magnet. Wind part of the wire tightly around the nail, as shown in the picture at the left. Make about ten turns of the wire. Scrape off the covering of the wire at each end so that about an inch of the wire is bare. Then fasten one end of the wire to the outside *binding post* of the cell. Fasten the other end of the wire to the post in the center. What happens this time when you dip the nail into the saucer of tacks? Is the nail a magnet now?

You have made an *electromagnet*. Electricity flowing from the cell through the wire makes a magnet of the nail. What kinds of material will this electromagnet attract? Will it pick up rubber, silk, glass, tin, or lead? Will it pick up steel pins and iron paper clips? Will it pick up an iron key? It attracts the same things that a bar or horseshoe magnet attracts —things that are made of iron or steel.

Now see if you can find one difference between a bar magnet and the electromagnet. First, pick up some tacks with a bar magnet. If you wish to remove these tacks from the magnet, you must pull them off. Next, pick up some tacks with the electromagnet. Watch the tacks carefully while you remove the wire from one of the posts of the dry cell.



How can you make the thumb-tacks fall from this electromagnet?

When you unfasten the wire, the tacks fall from the nail. The nail no longer has any "pull," and it cannot hold the tacks. What has happened to cause this change? When you unfasten the wire from the dry cell, you shut off the electricity. The electromagnet has no force to pull iron or steel unless electricity is flowing through the wire. So, as soon as the electricity is shut off, the electromagnet drops

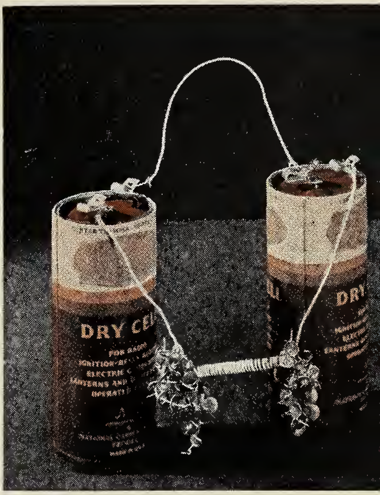
This big "skull-cracker" ball weighs over 4800 pounds. It is picked up by the electromagnet and dropped on the iron below to break the iron.

its load. Do you see one of the differences between a bar magnet and an electromagnet? An electromagnet has force only when there is electricity flowing through the wire that is wound around it.

Now can you explain why the big circular object attached to the crane could pick up and drop its loads of iron? The circular object was an electromagnet. Electricity was used to make it work. When the man shut off the electricity, the electromagnet lost its force and dropped its load of iron. When he was ready for the electromagnet to pick up another load of iron, the man turned the electricity on again.

Before you do any more experiments with electric cells, you should learn something that will help you keep the cell from wearing out. When you are not using an electromagnet, you should always remove the wire from one post of the dry cell. If you do not do this, the dry cell will soon be worn out.

Do you know how to make the force of an electromagnet stronger? Here is an experiment that will show you one way to do so. First, count the number of tacks the electromagnet will pick up. Then unfasten the wire from one post of the dry cell and wind nearly all the wire tightly around the nail. Again fasten the wire to the post. How many tacks will the electromagnet pick up this time? This experiment shows that more turns of wire on an electromagnet give it greater force.



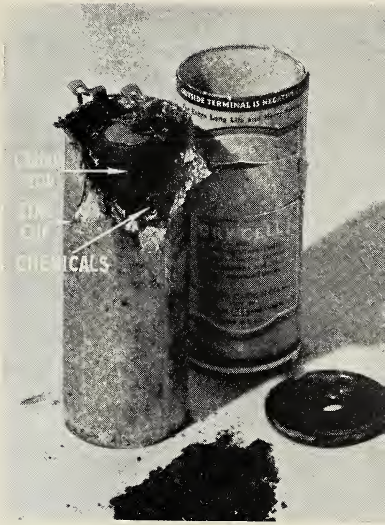
Tell two reasons why the electromagnet shown in this picture is stronger than the one shown in the picture on page 151.

You can discover the second way of making an electromagnet stronger by doing this experiment. Study the picture carefully to find how to connect two dry cells to the electromagnet. Then connect them and count the number of tacks that the electromagnet will hold. Did you find that still more tacks were attracted to the magnet? Two dry cells connected just as they are shown in the picture make the current of electricity stronger than it is when only one cell is used. When a stronger current of electricity is used, the electromagnet has greater force.

1. How can you use a dry cell, a piece of covered copper wire, and a nail to make a magnet? What is this kind of magnet called?
2. Tell two ways in which you can make the force of this electromagnet stronger.
3. How is an electromagnet like a bar magnet? How is it different?
4. Have you ever seen an electromagnet being used to lift things? If you have, tell what you saw.

Where does electricity come from?

To begin finding out where electricity comes from, suppose you break open an old, worn-out dry cell to see what it is made of. Pull off the cardboard covering and notice the metal beneath it. This metal container is zinc, and it is called a *zinc cup*. Break off the top and take out about half the black mixture that is inside the zinc cup. You can now see a black rod in the center. This is a *carbon rod*. Notice the black mixture that you have taken out. In this mixture are some chemicals. Does the mixture have a strange odor? Different chemicals are used in the various kinds of dry cells, but all dry cells have a zinc cup with a carbon rod. A dry cell is not really dry. As you have found out, the mixture in the zinc cup is moist. The top is sealed to keep the moisture inside.



If you look carefully at the worn-out dry cell, you will probably find some holes in the zinc cup. You may also find some white powder on it. What do you suppose made these holes and also the white powder? From your fifth-grade science study you remember that materials can change into other kinds of materials. This is called a chemical change, and it is the kind of change that happened in the dry cell. Part of the hard zinc was changed to a soft white powder by the chemicals in the cell. This change made electricity in the cell.

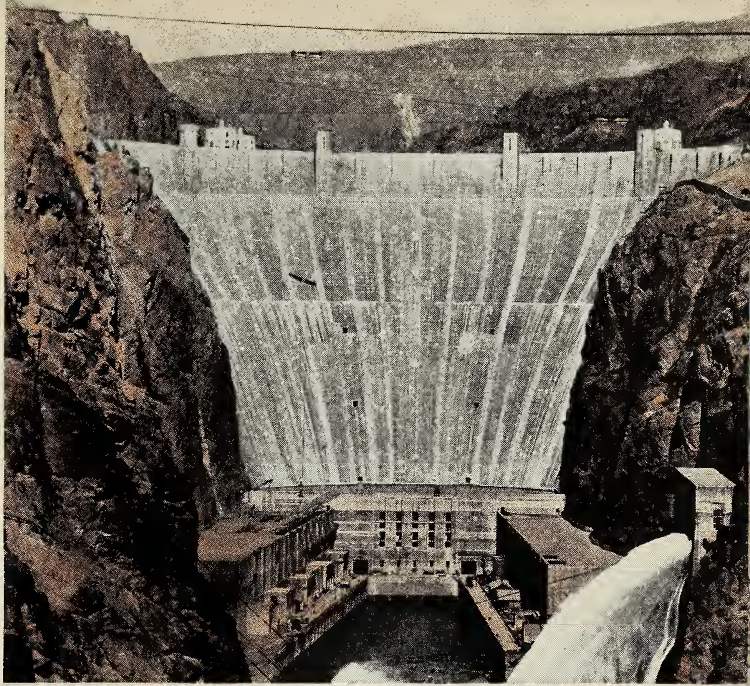
After holes are made in the zinc cup, the chemicals in the cell become dry. When this happens, the chemical changes going on in the cell stop, and the cell can no longer make electricity. We say that the cell is *dead*. Look around to see how many places you can find where dry cells are used.

There is another kind of cell that makes electricity. It is called a *wet* cell, because a liquid is used in it. When two or more cells are used together, we have a *battery*. There may be a battery of dry cells or a battery of wet cells.

In an automobile there is a battery that supplies electricity. This battery is called a *storage* battery. It is usually made of three wet cells. But these cells in the storage battery are quite different from the ordinary dry cells or wet cells. If the cells in the storage battery become dead, they can be *charged* again. That is, they can be made to furnish electricity again by running a current of electricity through them for a while.

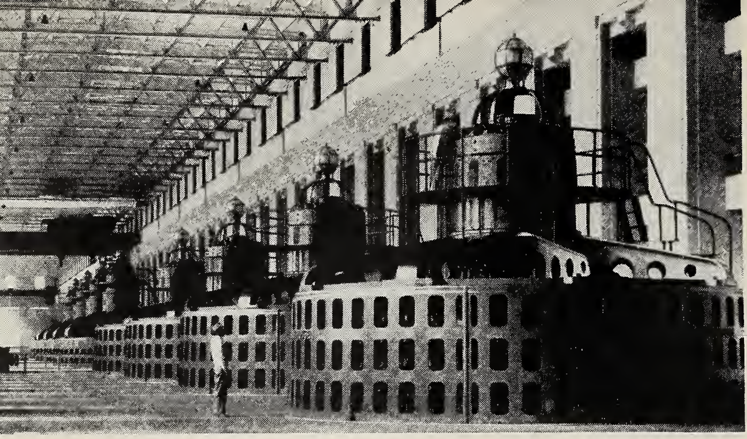
Of course you know that the electricity for your lamps, toasters, flat-iron, and lights is not made by a large number of cells stored away somewhere in the house. Wires come into your home from somewhere outside, and your parents have to pay for the electricity you use. Where does this electricity come from? Perhaps the electricity in your home is made far away by the force of falling water. You have learned that swiftly moving water is very powerful. It can turn a wheel, and this wheel can turn other wheels attached to it to run machines of all kinds. In this way the force of moving water is used to make electricity.

Great whirling water-wheels run machines called



In a power-plant like this one at Boulder Dam there is a deep lake behind the dam. Below the dam there are water-wheels. The falling water shoots through these wheels with great force. The wheels turn rapidly and run big generators like those on the next page.

electric *generators*. These generators can make powerful electric currents. The force of the electricity made is so strong that electricity can be sent over wires to places hundreds of miles away. The electricity used in Los Angeles is made by water-power in the mountains 250 miles away. Part of the water flowing over

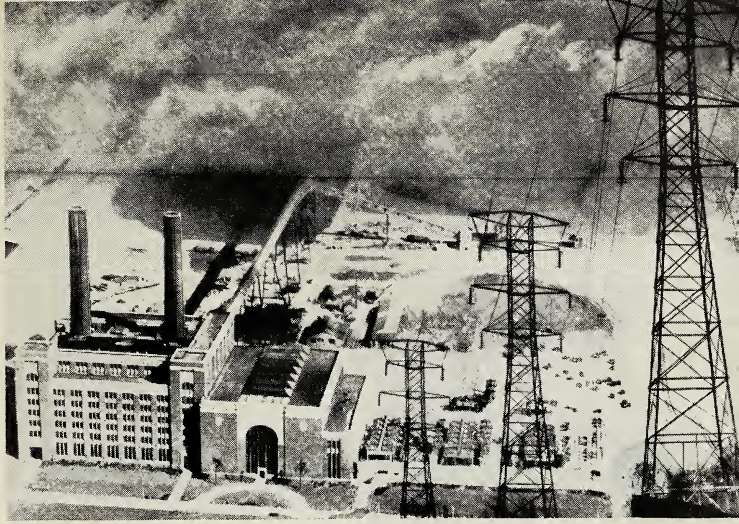


In the buildings at the foot of Boulder Dam are huge generators like these. The force of the falling water turns water-wheels which run the generators to produce electricity.

Niagara Falls is made to fall on huge water-wheels which turn generators that make electricity. In the past few years many new plants using water-power to make electricity have been built. As you travel across the country, you may see the tall steel towers that support the heavy wires of copper or aluminum over which the powerful electric current flows.

Many power-plants are run by some other force than the force of running water. Often the electric generators are run by the force of steam. In this way the force of steam is changed to electric force.

Electricity is a force. You cannot see electricity, and you cannot see many of the other forces. For example, you cannot see gravity. If you throw a ball up into the air, you know that gravity will pull the



Does your town have a power plant like this? Steam furnishes the power to run the electric generators. Heavy wires go out from it and carry powerful currents of electricity. The wires are held up by tall steel towers.

ball to the earth. You can see the ball fall, but you cannot see the force of gravity. And you cannot see the wind, but you can see things that are being moved by the wind. You can see a small piece of iron moving to a magnet, but cannot see the *force* of the magnet.

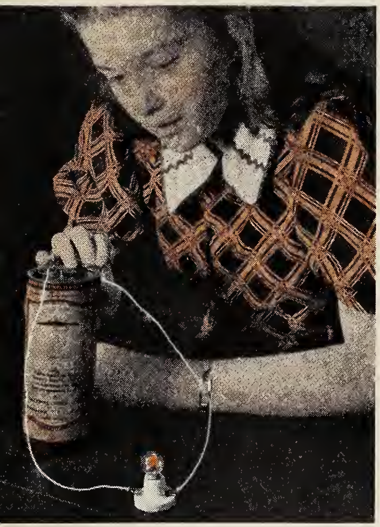
1. If you are talking about one dry cell, why is it not correct to call it a "battery"?

2. Why do dry cells become "dead"?

3. Name two forces that are used to run the generators which make electricity.

How do we get electricity to the appliances in our homes?

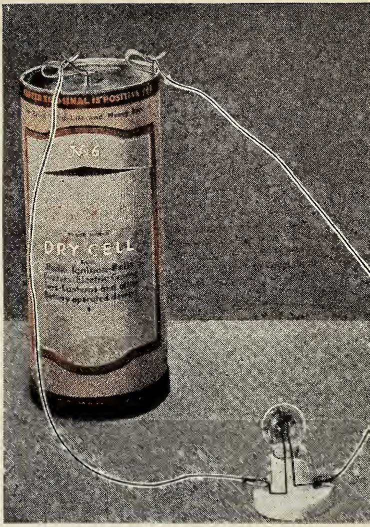
TO FIND OUT how electricity moves from one place to another, get some copper wire, a small electric flash-light bulb and socket, and a dry cell. Connect one piece of copper wire from the light bulb to one binding post of the dry cell. Does the bulb light? Connect another piece of copper wire between the other two binding posts of the bulb socket and the dry cell. Does the bulb light now? Why do you think it lights when two wires are used but does not light when only one wire is used?



Trace the path that has been made for the electricity so that it can travel through the light bulb.

Study the wires and see if you can trace the path that the electricity follows as it flows along. It travels from one binding post of the dry cell, through the wire in the light bulb, then on to the other binding post of the bulb and back to the cell.

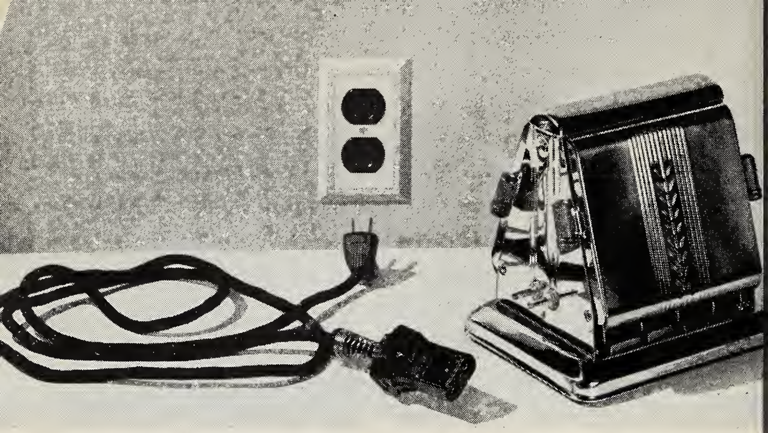
If electricity made a black line as it flows, your wires and bulb would look like those in the picture on this page. Trace the black line from one binding post of the cell through the bulb and back again to the cell. Can you see that electricity flows back to the place from which it starts? It will not go part way. If it cannot travel all the way, it will not flow at all. The path in which electricity travels is called a *circuit.*



Electricity will not flow unless there is a *complete* circuit. A piece of wire missing from the path, or circuit, will make a break in it. Then electricity will not flow over it. If you disconnect one of the wires leading to the bulb, the light immediately goes out. Bring the end of the wire so near the binding post that it is almost touching. Does the bulb light?

The bulb will not light until the wire and the binding post are really touching. Small as it is, this break in the circuit keeps the electricity from flowing. A circuit must be complete before electricity will flow over it.

If you examine the cord of an electric toaster,



Find the socket, plug, and prongs that make the circuit complete when the toaster and cord are connected.

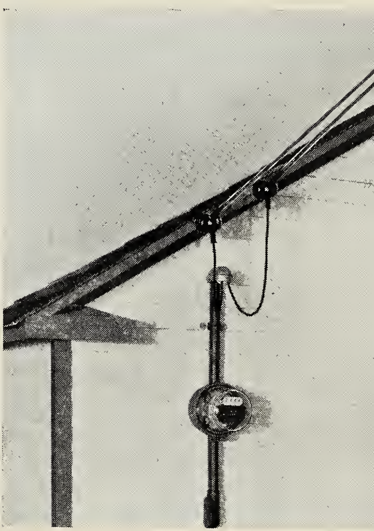
you will learn how we get a complete circuit of electricity through the toaster. Do you find that the cord is made of two wires twisted together? On one end of this cord is a *plug* with two prongs. Notice that each prong is connected to one of the wires in the cord. At the other end of the cord is a *socket* that fits tightly over two prongs in the toaster. When the cord connects the toaster to the house current, electricity travels into the toaster over one wire and out over the other wire. This makes a complete circuit through the toaster.

Examine the cord that you use with an electric iron. Does it have two wires, also, and two prongs? In the electrical appliances that you use at home there will always be one wire for the electric current that comes in and another wire for the current going out. This makes a complete circuit for the electricity to travel over.

Do you know how electricity gets to your house? Gas and water are brought into your house by pipes. But electricity comes to your house over wires from the big power-plant where it is made. Can you find the place where electricity comes into your house? Notice that there are two wires. Why could there not be just one wire to your house for the electricity to travel over? There must always be a complete circuit of wire for electricity to travel over.

When you are using electric cords and an appliance such as a toaster or an iron, remember that you are no longer using a small current of electricity from a dry cell. You are using electricity that flows in a strong current. You must be careful to handle this strong current safely. If it is handled properly, electricity is a good helper.

But if electricity is handled carelessly, it can burn and kill. So, when



Two wires carry the electricity to the house from the main line along the street or road.

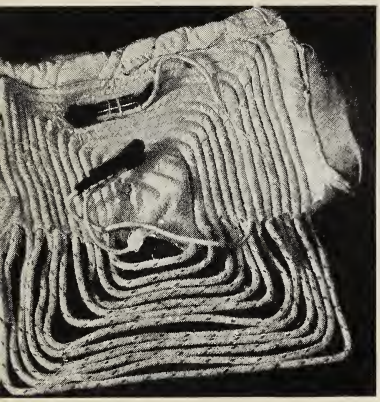
you connect any kind of electrical appliance with the main house-current, be sure to follow these rules:

Safety Rule Number 1. Disconnect all electrical appliances when they are not being used.

Safety Rule Number 2. Turn the switch off in an electrical appliance before you connect the appliance to the house circuit and also before you disconnect it.

Safety Rule Number 3. Never use an extension cord or an appliance that you know is out of repair.

Safety Rule Number 4. Never experiment with a cord or an electrical appliance that is attached to the main electric current.



This electric heating pad has been torn apart so that you can see how it is made. Electric heating pads may be very dangerous if out of repair or not used correctly. Find out how to use these pads safely.

1. Describe what happens to an electric current when there is a "complete circuit."

2. Explain how we get a complete circuit in an electric iron or a toaster.

3. How do you pronounce the word "circuit"?

Why are electric wires covered?

If these wires are bare, why doesn't the bulb light?

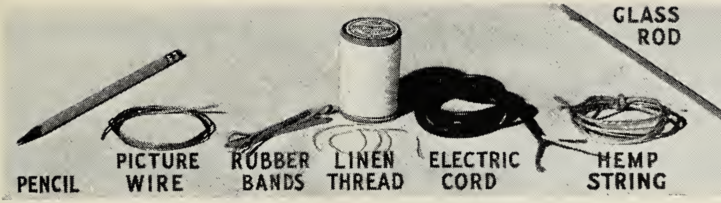
TO FIND out why nearly all the electric wires we use are covered, first do an experiment in which you use some bare wires. Connect a flash-light bulb to a dry cell, using bare wires. Then touch the wires together, as shown in the picture, and watch what happens. Do you know why the light goes out? Is electricity flowing through the wires to the bulb? Now feel the wires between the point where they are touching and the dry cell. Why do you think that electricity is flowing there?

The electricity has taken a short cut. This short cut is called a *short circuit.* When the two wires touched, they made a complete circuit, but a shorter one. Immediately the electricity went along the easier path. The light went out because the electricity could complete the circuit easier by flowing from one wire to another than it could by going through the wires in the lamp bulb. As soon as you separated the wires, the electricity flowed around the circuit from cell to bulb and back to the cell. Then the bulb lighted.

You can see that electricity would not be very useful to us if we could not make it go where we want it to go. It would not do useful work for us if it took a short cut back to the place where it started, instead of going on to the place where we want to use it. If there is a short circuit in the wires in your home, the lights go out. A short circuit in the wiring of an automobile may keep the motor from running, or it may put the head-lights out. We must therefore try to prevent short circuits. Let us see one way in which this is done.

You already know that nearly all the electric wires you see are wrapped with a tight covering. If you examine electric wires, you will find that this covering is usually made of cotton, silk, or rubber. Connect a flash-light bulb to a dry cell. Use covered wires. Now touch the two wires together the way you did when you used bare wires. Does the lamp still stay lighted, or does it go out?

You see from this experiment that electricity will not travel through the material that covers the wire. Electricity will not flow through cotton, silk, or rubber. A material through which a current of electricity will flow is called a *conductor*. Copper, silver, and brass are conductors of electricity. Materials through which a current will not flow are called

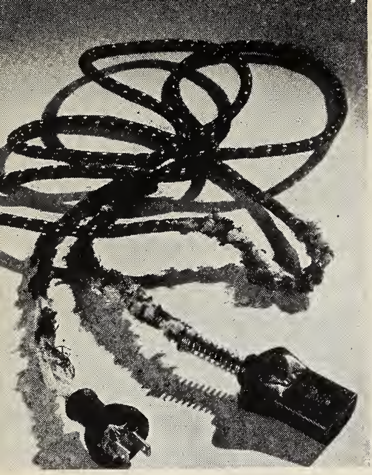


How can you find out which of these materials are conductors and which are insulators?

non-conductors. They are also called *insulators.* Wire that is covered with an insulator is called *insulated wire.* Sometimes wire is insulated with a coating of enamel. Glass and porcelain are also insulators. They are used to hold the wire on electric-light poles. The experiment you did shows that one way to prevent a short circuit is to insulate the wires. Then, even if the wires do touch each other, the electricity will not flow through the covering, which is an insulator.

Electricity may be dangerous when it takes a short cut. Try the short-circuit experiment (page 165) again, and find out why this is true. Connect the light bulb to the dry cell with bare wires. When the bulb is lighted, feel the wires. Do they feel warm? Now bring the wires together near the dry cell, keeping your fingers on the part of the wire where the current is still flowing. What happens to the wire? Does it suddenly become hot? Be careful not to burn your fingers.

You can see from this experiment that a short circuit makes a wire get hot. The wires in your home would become very hot if the bare wires were allowed



Why is this cord not safe to use?

to touch each other. They might become so hot that they would set fire to the wood near them.

But the danger of short circuits is not the only reason why wires are insulated. Have you ever had a shock from touching bare wires? Such a shock can be very serious. If you take hold of a bare wire in which a strong electric current is flowing, you will be badly burned. You may even be killed. You can see, then, why wires must be insulated. You can also see the reason for:

Safety Rule Number 5. Never use an electric cord or touch electric wiring on which the insulation is worn.

* * *

1. What causes a short circuit?

2. Why is it necessary to scrape the insulation from the end of a wire before you fasten it to a binding post of a dry cell?

3. Choose correct endings for this sentence: Electric wire is insulated (*a*) to make it last longer, (*b*) to make it safe to handle, (*c*) to prevent short circuits, (*d*) to keep it clean, (*e*) to keep it from getting hot.

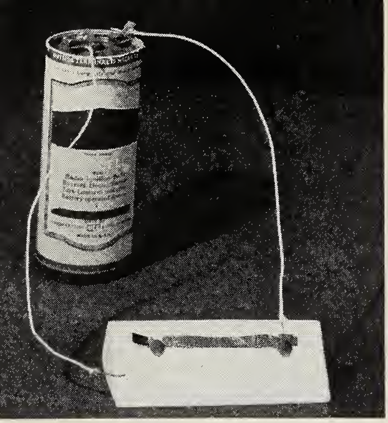
Here is the "policeman" that guards your home.

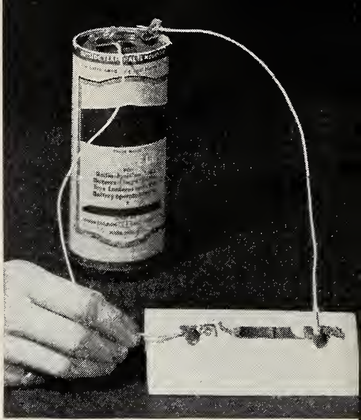
How do we protect our homes from short circuits?

Sometimes our buildings catch fire from short circuits, but more often this is kept from happening because scientists have worked out a way to protect us from the dangers of short circuits. In every home there is a "policeman" on guard in the electrical circuit. This "policeman" is a *fuse.* All the electrical current you use passes through fuses before it goes to your lights, vacuum-cleaner, and other appliances.

Have you seen what happens to one of these fuses when something goes wrong with the electrical circuit? Perhaps your mother was using an electric iron when all at once something in the iron went s-s-s-s-t! Instantly the electricity was off. Probably the insulation in the iron or the cord was worn, and the bare wires had rubbed together, causing a short circuit. The current went off because the fuse "policeman" was guarding your home against the short circuit. The "policeman" turned off the electricity.

How do you think this small policeman turns off the current so cleverly? Get a new fuse and look through the cover. Can you see a thin strip of metal inside? This piece of metal is very important because the electrical current flows through it.





An experiment will show you how this piece of metal helps protect your home. Get a strip of tinfoil and put it on a block of wood. Then connect two pieces of copper wire to a dry cell. Hold the wires so that each is connected with one end of the tinfoil. The tinfoil is a conductor of electricity; so the wire and the tinfoil make a complete circuit. Watch the tinfoil closely. What happens to it? When the tinfoil melts, it breaks apart. What happens to the electric circuit? Is it still a complete circuit? Will electricity flow over it? What has broken the circuit?

Do you know why the tinfoil melts, although the copper wire does not melt? In your study of science you have already learned that some metals melt easily, while other metals need much heat to make them melt. The tinfoil melts quickly because only a little heat is needed to melt it.

You can now tell how a fuse turns off electricity when there is a short circuit. A short circuit, you remember, heats the wires. It also heats the strip of metal in the fuse. This metal needs only a little heat to melt it, and when the metal melts, it breaks the circuit. We say that the fuse has "burned out" or "blown out." When the repair man comes, he first finds out where the short circuit is. Then he repairs the wires. If the heat has melted them apart, he connects them or puts in new wires. He also carefully covers them with new insulating material. Then he puts in a new fuse. Once again there is a current of electricity, safely traveling over its path of insulated wire.

Safety Rule Number 6. Never try to repair a "blown-out" fuse. Use a new one.

Safety Rule Number 7. When a fuse "blows out," always put back a fuse that will carry the same electric current. For example, if a fuse is labeled 10A, the new fuse should be labeled 10A.

* * *

1. Put these sentences in the correct order to tell what happens when a fuse burns out.
a) The metal strip in the fuse melts.
b) There is a short circuit.
c) The wires heat.
d) The current stops flowing.
e) The circuit is broken.

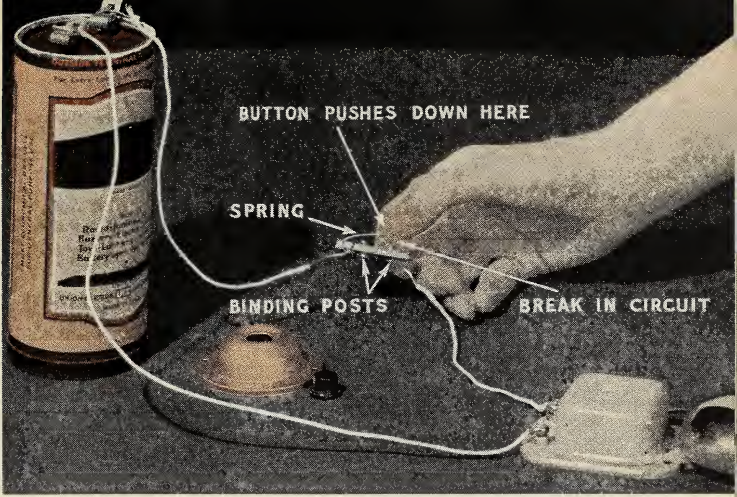
2. Why may a short circuit be dangerous?

How do we control electricity?

You come into a room and push a button. The light goes on. You push the button again, and the light goes off. In just about the same way you turn the electricity on and off for a toaster, an electric iron, a vacuum-cleaner, and the lamps on an automobile. Electricity is certainly a convenient kind of force, because we can turn it on and off so easily to do the things that we need.

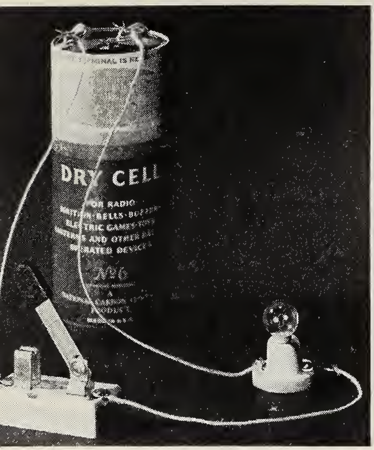
What you have already learned about an electrical current should help you tell what happens when you turn the current of electricity on or off. But to help you understand more clearly what happens, try this experiment with a push-button and an electric bell. Connect the push-button and the bell to a dry cell as shown in the picture. Does the bell ring as soon as the wires are connected? Now try pressing down on the button. Pressing the button turns on the electricity and rings the bell.

If you examine this little push-button, you can find



out just how it turns on electricity. The picture shows the important parts of the push-button. Do you see that the button pushes down on a small strip of brass? This strip of brass is a spring. One binding post of the push-button goes through this spring. When you push the button, you press the spring down so that it touches the other binding post. This makes a complete circuit.

Remove your finger from the push-button and notice the gap. Electricity cannot flow, because the circuit is broken by this gap. The push-button is a kind of *switch*, and switches are used to turn electricity on and off. When you "turn on" electricity, you make the circuit complete so that the electric current can flow all the way around it. When you "turn off" electricity, you break the circuit.



What would you do to make a complete circuit here so that the bulb would light?

Switches help us control electricity by turning it off and on as we need it. We can control electricity in another way, too. We can make the current weaker or stronger. When you connect two dry cells to the electromagnet, the electromagnet has more force than when only one cell is used. The two dry cells made a stronger current of electricity than one dry cell.

If you had added more dry cells, connected in the same way, the current would have been still stronger. Connect a toy motor to a dry cell. Notice how fast the motor runs. Then, one at a time, add two or three more cells. Be sure to connect them as shown in the picture on page 153. Each time you add a cell, notice how much faster the motor runs.

If you got a toy electric train for Christmas, a transformer came with it. A *transformer* "steps up" or "steps down" the strength of an electric current. The transformer with your electric train "steps down" the strength of the current so that you will not be hurt by it when playing with the train. This kind of transformer is also used with many door-bells.

Safety Rule Number 8. Have a switch repaired at once if you get a shock when you turn the electricity on or off.

* * *

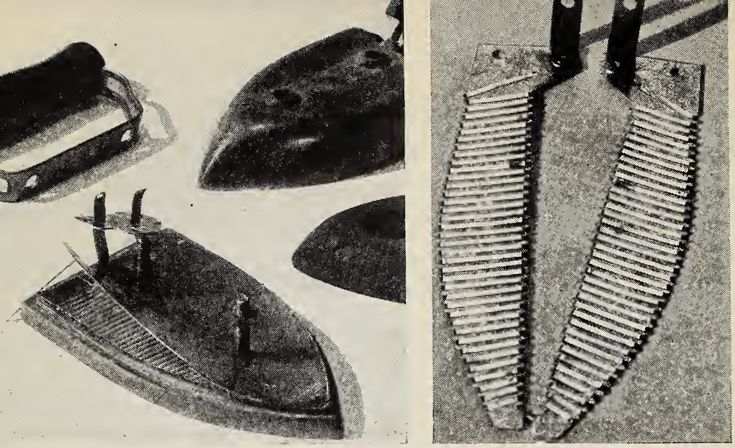
1. Explain how a push-button works to ring a bell.
2. How can you make the electric current stronger or weaker in your experiments with cells?
3. Name four places where you have used a switch or a push-button to control electric current.

Where do we use electricity to make heat?

In some of the experiments you have done, you have noticed that the electric wires you used became hot. You also know that you can toast or even burn bread with an electric toaster, you can iron clothes with a hot electric iron, and you can warm yourself with an electric heating pad. How does electricity make these things hot?

Connect a short piece of fine iron wire between the binding posts of a dry cell. Watch the wire and put your finger near it from time to time. Does it get hot? The electricity has to push hard to get through iron wire; so it heats up the wire. Any poor conductor gets hot as electricity passes through it.

Now you can understand why an electric toaster gets hot enough to toast your bread. Examine the



If you take an old iron apart, you will find flat wire wound around a thin piece of *mica*. Mica is a non-conductor of electricity.

flat wires in a toaster. You can tell by looking at them that they are not made of copper. Connect the toaster to the electric current and watch the wires get red-hot. The wire in the toaster is probably made of a material called *nichrome*. This is a mixture of nickel and chromium. Nichrome is a very poor conductor of electricity.

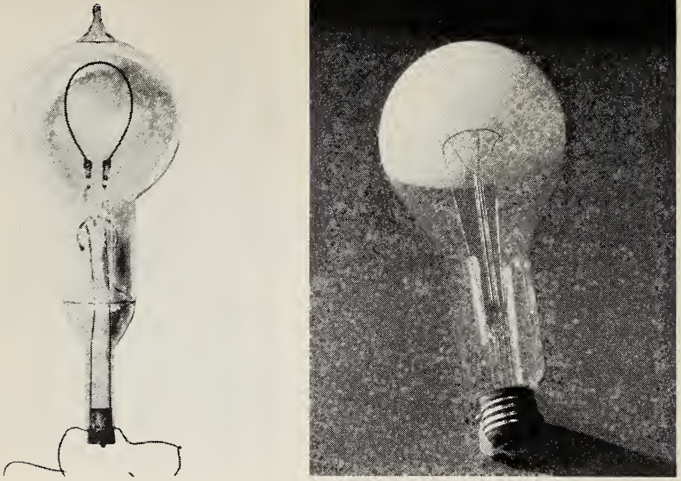
What do you imagine is inside an electric flat-iron to make it heat up? Get an old worn-out iron and take it apart to see if you were right. Did you find the same kind of nichrome wire? As the electricity pushes its way through this nichrome wire, the wire gets red-hot and heats the iron. Plug in an electric heater, a hot-plate stove, or a toy stove and watch the wires get red-hot. Whatever kind of wire is used in these, you know that the wire is a poor conductor. The electricity must push hard to get through it. This makes the wire get hot and give the heat that we want to toast our bread, to iron our clothes, to cook our food, or to warm us.

1. When we want electricity to heat a wire, do we use a good conductor or a poor conductor?
2. Why does electricity make some wires get red-hot?
3. The wires in our homes and other buildings carry electricity without getting hot. Why do they not get hot?

How does electricity make light for us?

You have already learned a number of things to help you understand how electricity makes light. You know that electricity can make wires hot. It can make them so hot that they glow. When anything glows, it gives off light.

About sixty years ago Thomas Edison began to wonder whether there was not some way to make an electric light. Of course, he first had to find some kind of material that would glow with a bright light. Such a material was hard to find, because it had to conduct electricity, and it had to get very, very hot without melting. Mr. Edison tried out hundreds of different



At the left is a picture of one of the first kinds of electric-light bulbs made. At the right is a new tungsten lamp.

materials. Finally he was able to make a carbon thread that did what he wanted it to do. The first electric-light bulb had a carbon thread in it.

But carbon threads did not work very well. The hot carbon gave off light, but the heat made the carbon fall to pieces in a short time. The first successful electric-light bulb lasted only about forty hours. So scientists went to work to find a better material. They needed a material that would last longer and give off a better light as electricity pushed through it.

To find out what is used in electric lamps today, suppose you get a worn-out electric-light bulb and break it so that you can examine the wires inside. Be careful how you break it, because the glass may shatter and cut your face and eyes. It is a good plan to hold the bulb under water when you break it, or put it in a cloth sack. What do you find inside? You find a very fine, silver-colored wire. It is almost as fine as the hair on your head. A fine wire like this is called a *filament*. Take hold of the wire and pull it out as long as you can. Do you see that a long wire was coiled up in a small space? When electricity flows through this wire, it heats the wire to a white heat, and the wire gives us the light that is so helpful to us.

Today, the wire in our bulbs is made of a metal called *tungsten*. This metal lasts for hundreds of hours and gives a brilliant light. Tungsten is such a poor conductor that electricity has to push very, very hard to get through. This makes the wire get so hot that it becomes white, and the white-hot wire gives off a bright light.

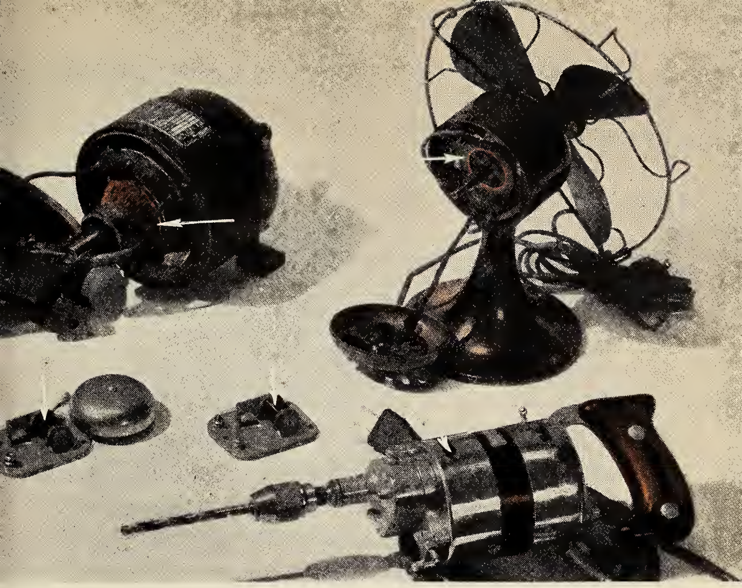
A few years ago another method of using electricity to make light was discovered. Scientists found that certain gases will glow and give off light when a current of electricity is passed through them. One of these gases is *neon*. Signs are made by sealing neon in a tube of glass and sending electricity through it. The neon gas glows with a red light. Some of our buildings are now lighted by tubes of gases, for scientists have discovered that other gases can be made to glow with a brilliant light by passing electricity through them. Different kinds of gases have been found to give out light of different colors. Many advertising signs are made of tubes of gases.

1. Which is hotter: a red-hot wire or a white-hot wire?
2. What is a filament?
3. Why is copper wire not used in light bulbs?
4. Why is tungsten a good material for a light filament?
5. Why was Mr. Edison's first electric-light bulb not very successful?
6. What is a neon light?

How is electricity used to move things?

ONE EVENING when Howard Jones was making an electromagnet, his father said, "If you look around, you can find some electromagnets at work right here in our house." Suppose you imagine that you are making a hunt for electromagnets in your own home. The kitchen is a good place to start. Look for things that you know are being made to move by electricity. Wherever you see electricity moving something, look for an electromagnet.

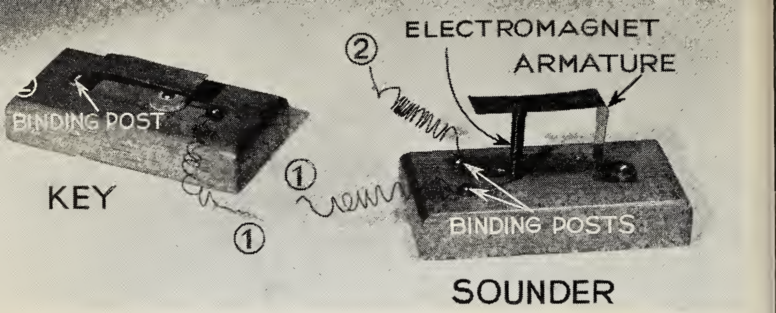
Perhaps while you are hunting around in your kitchen, the door-bell rings. Quickly you look at the bell and see the hammer striking it. Can there be an electromagnet anywhere in the bell? The way to find out is to look inside it. When you remove the box-



In each appliance is an electromagnet that makes part of the appliance move. The arrows point to the electromagnets.

like cover, you see two coils of wire wound around an iron rod. You have found an electromagnet!

On you go to the living-room. There you see the blades of an electric fan whirling around. Is there an electromagnet inside? In the picture on this page you can see the parts of an electric fan. Find the motor. An electromagnet, you see, is part of the motor, and the motor turns the blades of the fan. If you look at other electrical appliances that have moving parts, you will find that there is always an electromagnet in them.



At Number 1 connect a wire from the key to the sounder. At Number 2 connect wires to a dry cell.

The first invention to use the electromagnet was the telegraph. You probably have read that the telegraph was invented by Samuel F. B. Morse. About one hundred years ago he made the first telegraph instrument and sent the first message over wires.

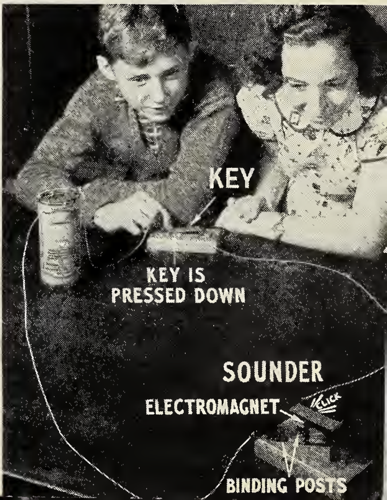
If you make a simple telegraph set like the one in the picture, you can easily understand how it works. First make the two wood bases out of any soft wood. Then make the electromagnet by winding insulated copper wire around a large iron nail. Drive the nail part way into one base. You had better first drill a little hole to keep the nail from splitting the wood. Next get two pieces of tin about three-fourths of an inch wide and four inches long. Bend one piece for the *armature* and the other for the *key*. After drilling a little hole in each of these, fasten them to the wood bases with screws.

To make binding posts for the wire, put two screws in the base of the sounder and one in the base of the key. Connect the set to a dry cell. Make sure that the armature does not touch the electromagnet. Also be sure that the key does not touch the screw beneath it. Now you are ready to find out exactly how the telegraph works.

Press down on the key so that the tin touches the screw. Do you hear the sounder click? Can you tell why it clicks? The key is just like a switch or a push-button. When the key is pressed down, it makes a complete circuit, and electricity flows through the coil of wire in the electromagnet. The magnet then pulls the strip of tin to it with a click.

When you take your finger off the key, the circuit is broken. The electromagnet no longer has any force to hold the piece of tin; so the tin springs away from the electromagnet and is ready to make another click when the circuit is closed again. In commercial telegraph sets the part that moves up and down strikes a screw above it, also. This makes another click.

To send messages, Mr. Morse worked out a code of dots and dashes for each letter of the alphabet. A dot is made by pressing the key down and letting it up very quickly. This makes

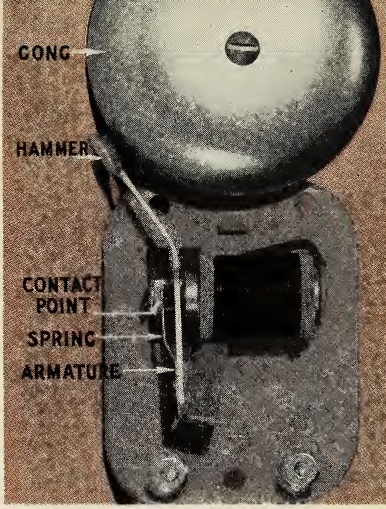


A · —
B — · · ·
C — · — ·
D — · ·
E ·
F · · — ·
G — — ·
H · · · ·
I · ·
J · — — —
K — · —
L · — · ·
M — —
N — ·
O — — —
P · — — ·
Q — — · —
R · — ·
S · · ·
T —
U · · —
V · · · —
W · — —
X — · · —
Y — · — —
Z — — · ·

the two clicks come close together. A dash is made by holding the key down longer; therefore the two clicks come farther apart. Can you use the Morse code, shown above, to send messages on your set?

You remember that when you hunted for electromagnets, you looked for something moving. What part in the telegraph does the electromagnet move? It moves the piece of tin above it. The movable part of any electrical machine is called an *armature.* When electricity flows through the electromagnet of the telegraph instrument, the armature is pulled to the magnet and makes a clicking noise.

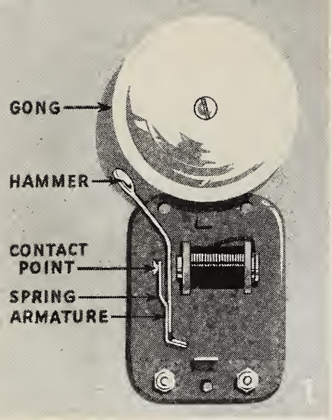
Can you find the armature in an electric bell? Connect an electric bell and a push-button to a dry cell. Remove the metal cover that is near the gong of the bell. The first thing you notice is the electromagnet. You already know that when you press down on the push-button, a complete circuit is made, and a current of electricity flows over the wire.

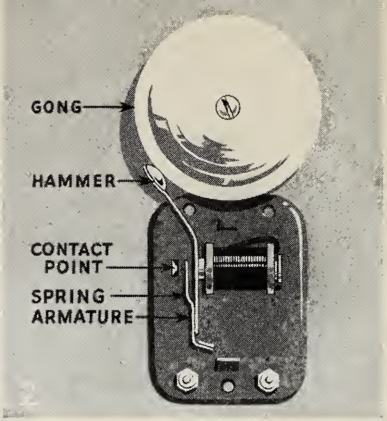


Watch carefully as you push the button to see what part of the bell is moving. Do you see the hammer moving back and forth quickly and striking the gong? The hammer is attached to the armature; therefore, when the electromagnet pulls the armature, the hammer strikes the gong.

But what makes the hammer move back and forth? This is the most interesting part of the electric bell. Examine the bell when it is not ringing. Notice that a little brass spring is fastened to the armature. This spring touches a point called the *contact point*, shown here and on the next page.

This contact point is the important part in the bell; so let us see what it does. You can see that the contact point and the spring are part of the electric circuit of the bell. Press the armature against the electromagnet and hold it there. Is the spring now touching the contact point? There is a space between the spring and the contact point, and the electricity cannot flow over this space. The contact point is like a switch. When the spring touches it, the electricity is turned on. When the spring is

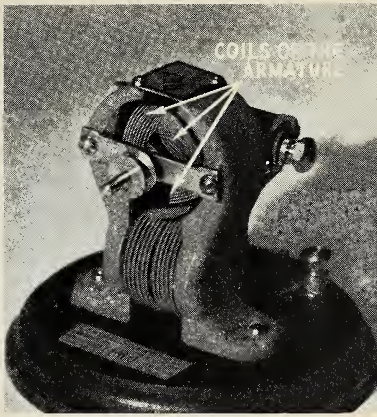




pulled away from it, the electricity is shut off, and the coil is no longer a magnet.

As you press the push-button, the spring and the contact point are touching (Picture 1); so the circuit is complete. When electricity flows through the coil of the electromagnet, the electromagnet pulls the armature, and the hammer strikes the gong (Picture 2). But as soon as the armature is pulled away from the contact point, the electricity is shut off, because the circuit is broken. So the electromagnet loses its force.

Then the spring pulls the armature back from the gong, which makes the spring touch the contact point again. This turns on the electricity, makes the electromagnet have force, and again the hammer strikes the gong as the magnet pulls the armature. At the contact point the electricity is turned on and off, on and off, many times a second. This makes the armature move back and forth rapidly. Do you see how rapidly the hammer strikes the gong?



You have seen that we use an electromagnet to ring a bell and to send messages by telegraph. You also know that there must be an electromagnet in an electric motor, because motors have a part that moves. Find the electromagnets in your toy motor. Find an armature in the motor. In the picture on this page the motor has three small electromagnets in the armature and a larger one below the armature. When the electricity is turned on, the three small electromagnets whirl around very fast.

Do you know why the electromagnets in the armature whirl around? Before you can find out, you will need to remember some things that you once learned about magnets:

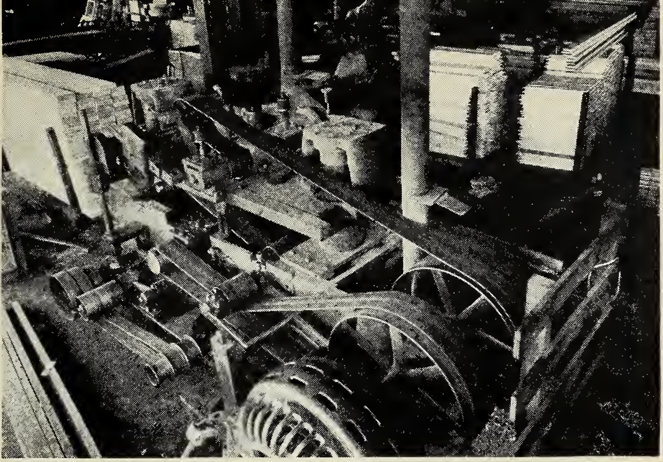
1. Every magnet has a north pole and a south pole.
2. *Like* poles *repel* each other; that is, the south pole of one magnet will push away the south pole of another magnet.
3. *Unlike* poles *attract* each other; that is, the north pole of one magnet will attract the south pole of another.

Now, does an electromagnet have a north pole and a south pole? To find out, test one with a bar magnet. Hang a bar magnet by means of a thread tied around the middle of the bar. Attach the electromagnet to a cell and bring one end of the electromagnet near the north pole of the bar magnet. What happens? Now bring the same end to the south pole of the bar magnet. What happens? How does the law of magnets help you prove that an electromagnet has a north pole and a south pole?

An electromagnet has a north pole and a south pole just like other magnets. And if two electromagnets are brought near each other, they act just as other magnets do. The like poles of the electromagnets push each other away. The unlike poles pull toward each other. Now you can understand how electromagnets make motors run.

In an electric motor the electromagnets are arranged so that the pushing and the pulling of the poles whirls them around and around. Of course, they whirl only when the electricity is flowing, because they do not have any force in them unless an electric current is flowing through the hundreds of coils of wire that are on them.

The wheels of toy machines can be connected by belts to a toy motor. Then, when the motor runs, it will run the machines. Large machines are connected to big motors in the same way. All over the world

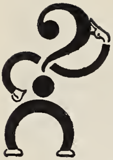


Here you see a motor running a machine in a wood-working mill. The motor turns two big wheels connected to it. They turn many smaller wheels that are connected to them by belts.

electricity is doing work for us by turning millions of wheels. And wherever wheels are being turned by electricity, you can be sure that electromagnets are making them turn.

* * *

1. What is an armature?
2. When you push the button of an electric bell, why does the hammer not stay against the gong?
3. What important part do we always find in an electric motor?
4. Explain why a motor would not run if the electromagnets did not have poles.
5. Why would a bar magnet be unsatisfactory in a telegraph set?



Questions to Answer

1. What safety rules should you follow in connection with electricity? Tell why it is important to observe each of these rules.

2. Tell three important ways in which we use electricity.

3. Could we get light from electricity if we could not get heat from it? Explain the reasons for your answer.

4. What is an electromagnet? When does an electromagnet not have any force?

5. For what purposes are electromagnets used?

6. Suppose that you connected a toy motor and a push-button to a dry cell, but the motor failed to run when you pushed the button. What things would you check to find out why the motor did not run?

7. If the electricity "goes off" in your home or town, what things stop working? Make a list of them. What are some of the things that may happen to stop the electricity in your home?

Things to Find Out

1. Find out where your town's electric power-plant is located. Perhaps you can visit it. What kind of force is used to run the generators?

2. Where does the electric current enter your home? Why are two wires used?

3. If you have an electric stove, find out whether special wires are needed to carry this current. Are there special fuses for it? How are these fuses different from those for the lights?

4. Show by experiment that the following statements are true:

a) Electricity will travel through some materials but not through others.

b) Electricity will travel only over a complete circuit.

c) Electricity will travel over the easiest path.

5. Find out how automobile batteries are "recharged."

6. Find out where electromagnets are used in your home and school.

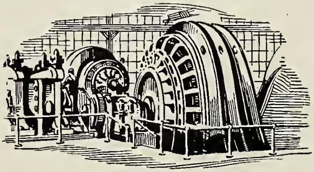
7. Try to find fuses, switches, and other electrical devices in your school.

8. Find out how electricity sometimes causes fires in buildings.

9. If you can do so, visit a telegraph office.

10. Read about the laying of the first telegraph cable across the Atlantic Ocean.

11. Get an old electric heating pad and take it apart to find out how it is insulated and what the wires are made of.



UNIT FIVE

HOW DO WE CONTROL FIRE?

How do we build fires?

THE BOYS of the Eagle Patrol had been hiking for several hours. This was John's first trip, for he had just joined the Scouts. So far, he had enjoyed himself greatly. But right now he had an empty feeling in his stomach, and he wondered, "When do we eat?" The patrol leader must have been thinking about this, too, for he stopped and said, "This looks like a good place. Shall we eat here?"

"Yes," shouted the boys as they took off their packs.

Everyone seemed to know what he was supposed to do. Some of the boys gathered dry twigs and branches to build the fire. While they were doing this, two other boys cut green twigs to use for holding the "hot-dogs" in the fire. The patrol leader looked about to find a good place to build the fire. John watched to see what he would do. First he selected a place that was away from the trees and bushes. Then he cleared away the dead leaves. "When you build a fire in the woods," he told John, "you must be sure that it will not spread to the bushes or trees; so we always build fires away from the trees and bushes, and we clear

The dead leaves were cleared away, and the sticks were piled up so that air could circulate around them.

away the dead leaves from around the spot where the fire is to be."

When the ground was cleared, the patrol leader carefully arranged the small twigs in a pile with their ends toward the center. Then he put some larger twigs and branches on top of them. When the twigs and branches were arranged, they looked something like an Indian wigwam. "We put the smaller twigs on the bottom," he said, "because they catch fire more easily than the big ones. We pile them up like this so that the air can get in and circulate around them.

"Which way is the wind blowing?" he asked. John thought this was a funny question, but he said, "I think it is coming from the north."

"You always light a fire on the side toward the wind," the patrol leader explained, "so that the heat from the flames will be blown up through the twigs." Then he struck a match, lighted the bottom twigs, and soon a good fire was burning. In a little while the wieners were well roasted, and everybody settled down to eat.

When the meal was over, some of the boys brought water from a creek near by and poured it over the fire. "We always put our fires out before we leave them," said the patrol leader. "If we can't find any water, then we cover them with sand or dirt."

When John got home, he told his father how they built the fire in the woods. "I have to build a fire in the furnace," his father said. "Maybe you would like to see how that is done." John thought this might be interesting; so he watched his father to see how he built a furnace fire.

Since there is no water nearby, this ranger is covering his campfire with dirt.

First his father opened the door of the furnace and looked in. "I guess I forgot to take out the ashes," he said. Then he picked up an iron handle, fitted it over a bar, and moved it back and forth. John could see the ashes falling in the space below.

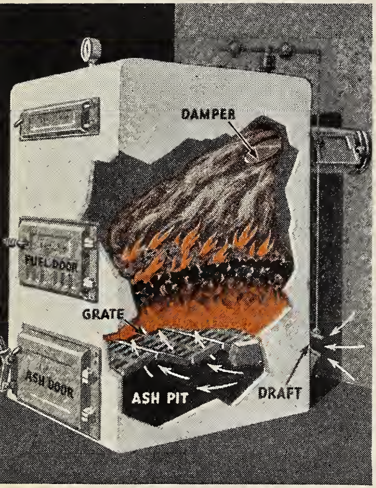
"Are they all out?" his father asked.

When John looked into the furnace, he could see some heavy iron bars moving up and down.

"That is the grate," said his father. "The bars move from side to side as I move this crank. The ashes can then fall through the grate into the ash pit below. Do you see that there are holes in the grate? These holes let the air come up from below."

Then John's father put some paper, some kindling wood, and a few larger sticks of wood into the furnace. He also put in a little coal. "I don't build a wigwam as you do in the woods," he continued, "but I do put the wood in so that air can circulate through it. Now let's look at the drafts and the damper. Our fire needs air; so we let air enter below the grate with this draft that I will open. Then we need to let the smoke and gases out. So we turn this damper in the pipe."

John's father then lighted the paper, and soon a hot fire was burning. "Now we can put on some



Drafts are arranged differently on different kinds of furnaces. How are they arranged on your furnace?

Which of these materials are combustible? How would you arrange the combustible ones to build a fire?

more coal," he said. "Coal won't burn until it is very hot. We will wait until the coal is burning well; then we can close the draft and the damper a little. If we leave them wide open, most of the heat will go up the chimney, and our coal will burn up too fast."

Before you read any farther, stop and think over what you have to do to build a fire. Think about building a fire in the woods and also in a furnace. What things do you have to do in order to build either kind of fire? Then read what follows.

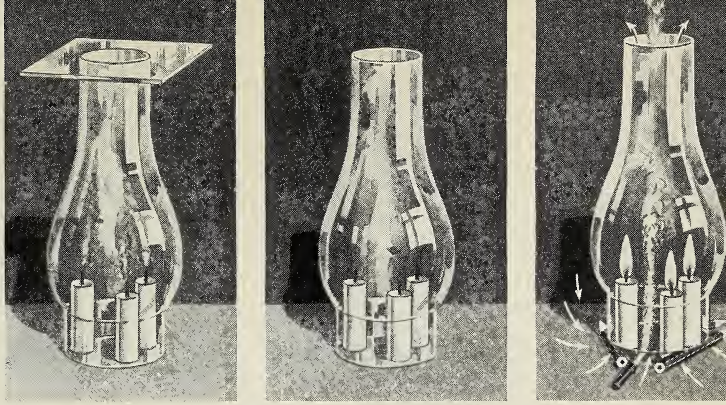
Of course, to build a fire you must first of all have materials that will burn. Some materials will burn, and some will not burn. Paper, wood, and coal will burn. Glass, iron, sand, water, rock, and bricks will not burn. Materials that burn are called *combustible* materials. The first thing needed for a fire is, therefore, some combustible material.

To start a fire, you need a material that will catch fire easily. Paper, dry twigs, leaves, dry grass, and shavings are such materials. Materials that catch fire easily are those that need only a little heat to make them burst into a flame. You cannot light a lump of coal with a match because the match will not make the coal hot enough to burn. But the heat from a burning match is enough to make paper or shavings burst into flame.

Scientists call the temperature at which a material will burst into flame the *kindling temperature*. If a material catches fire easily, we say that it has a *low* kindling temperature. If a great deal of heat is needed to make it burn, we say that it has a *high* kindling temperature. You can see that paper and leaves have a low kindling temperature, and that coal has a high kindling temperature.

In arranging the materials for your fire, you place materials with a low kindling temperature at the bottom. Above them you place materials with a higher kindling temperature. When you light the materials at the bottom of the fire, they burn easily. Then the heat from them passes upward through the other materials and heats them enough so that they, too, burst into flame.

Finally, you need a supply of fresh air to start a fire and to keep it burning. You can see why if you will do this experiment. Get three small candles, each about two inches high. Place them on a plate

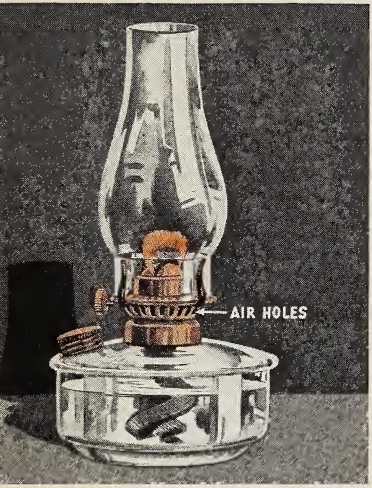


and light them. Put a lamp chimney over them and cover the chimney with a piece of glass. What happens? Perhaps you think that the candles will burn if you do not cover the top of the chimney. Try this. What do you discover?

Now place three or four short lead-pencils around the candles and set the chimney on top of them. As you see, the candles now burn. Light a piece of punk or of rag and hold it at the bottom of the chimney. Put out the blaze before you hold the punk or the rag at the bottom of the chimney. Where does the smoke from the punk or rag go?

The movement of the smoke shows you the way the air is moving. It goes in under the chimney and then up through the chimney and out at the top. In this way a current of fresh air moves past the candle flames. When you have a place for air to get in at the bottom, the candles get a supply of fresh air, as shown in the picture on this page.

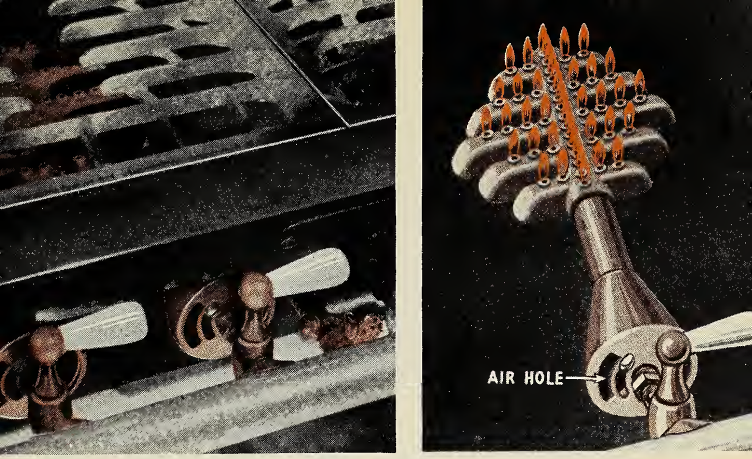
Do you see how these currents of air are made? The air in the chimney gets hot when the candles are burning. When air is heated, it expands and gets lighter. The colder air outside the chimney is heavier than the air in the chimney; so it enters the holes near the bottom of the chimney and pushes the hotter, lighter air upward. The same thing happens with open fires or with fires in furnaces and stoves.



Air gets to the flame through the holes below the chimney. What becomes of the old air as the new air enters?

Perhaps you wonder how air is supplied in a kerosene lamp. Look at the picture. Do you see how air gets in at the bottom of the chimney? Perhaps you have a gas stove at home. Look at the picture on the next page. Do you see how air gets to the fire in the gas stove?

There are, of course, other experiments to show that air is needed in burning. For example, did you ever try to burn a thick magazine? The paper has a low burning temperature, but still it does not burn easily. If the leaves are raised one by one, you



Gas comes into the burner of a gas stove through the pipe along the front. Air enters through the air holes and mixes with the gas. So when the gas is lighted, it has oxygen to keep it burning.

find that they will burn readily. Unless the leaves are separated, there is not enough air between them to let them burn. For the same reason a sheet of paper will burn more rapidly if it is held in the air than if it is lying flat on the floor.

You have learned so far how fires are built and why they are built the way they are. On this page and the next are four safety rules that you should always follow when you build a fire:

1. Do not build fires near trees, bushes, or grass that may catch fire. Clear away leaves, twigs, and grass from a space around the fire, so that it will not spread.

2. Do not build too large a fire. A small fire is better than a large one for cooking.

3. Before you leave it, always put out a fire by pouring water on it or by covering it with soil or sand.

4. When building a fire in a stove or furnace, never use kerosene or gasoline to help get the fire started.

* * *

1. What three things are necessary to make a fire?

2. Why are the materials with a low kindling temperature placed at the bottom of the fire?

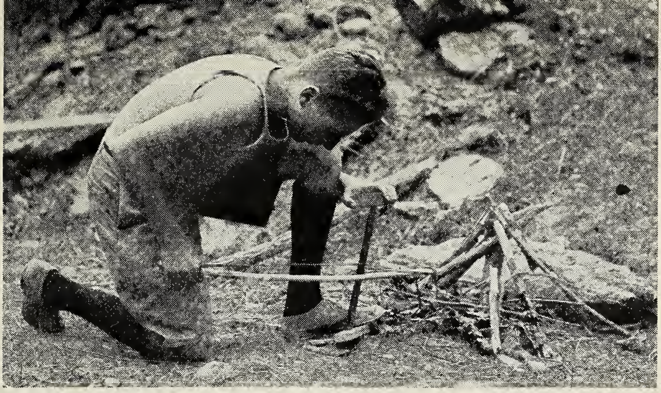
3. How could you do an experiment to discover whether soft coal has a lower kindling temperature than hard coal?

4. Why is each of the following parts necessary in a stove? (*a*) fire-box, (*b*) door, (*c*) stovepipe, (*d*) damper, (*e*) grate, (*f*) draft.

5. Explain why it is wise to follow each of the safety rules given on pages 201-202.

How do we light fires?

Now that you know what must be done to make a material burn, you can understand why we light fires the way we do. A long time ago, of course, there were no matches. Indians started fires by whirling a hard, pointed stick against a soft piece of wood. The friction of the two rubbing surfaces made heat. The friction made enough heat to raise the temperature of dry wood, leaves, or moss placed around the rubbing surfaces so that it would burst into flame. The Boy Scout manual contains directions



This boy is making fire in Indian fashion. The string of the bow is wrapped around the upright stick. When the boy moves the bow back and forth, it whirls the stick very fast. The end of the stick rubs on the block of wood on the ground and makes heat.

for lighting a fire in this way. It has been done in a little over six seconds.

Our great-great-grandfathers made fire by striking together a piece of flint and steel. The sparks made in this way fell on tinder (dry, decayed wood or scorched pieces of linen), that catches fire easily. Even today we use friction for starting fires in our modern friction gas-lighter or cigar-lighter. In these lighters a wheel of steel turns against a piece of flint to make sparks. The sparks fall on a wick soaked in gasoline. Gasoline has a very low kindling temperature and easily catches fire.

The first match that would light by rubbing the tip was invented only about 100 years ago. Match heads that light in this way contain materials which have a low kindling temperature. Therefore they can be heated hot enough to catch fire merely by the friction of the head against a rough surface. Matches have been greatly improved since they were first invented. Safety matches are made so that they must be struck against a specially prepared surface to catch fire. This makes them much less likely to be lighted accidentally. Some matches are made so that the heads will not fly off when they are struck, and the sticks will not glow after the flame is out. These are the safest matches.

1. How can a fire be started by the method used by the Indians?
2. Why did our great-great-grandfathers use tinder in starting a fire?
3. What improvements have made matches safer?

What happens when things burn?

ALL YOUR LIFE you have seen things burning. Your father burns wood, coal, coke, oil, or gas to heat your home. In the kitchen your mother may use kerosene, gasoline, or gas to cook your meals. If you live in the country, perhaps you have kerosene or gasoline lamps to supply you with light. All the materials just mentioned are *fuels*. A fuel is a material that we burn to get heat or light.

The next time you sit near a fireplace, notice how much heat and light are given off as the fuel burns.

Some of our fuels, such as wood and coal, are solids. Some, such as kerosene and gasoline, are liquids. We use a gas fuel to burn in furnaces and cook stoves. In some ways all fuels burn alike. Let us see what happens when any kind of fuel burns.

First of all, when a material burns, it produces something that we can feel. If you have ever put your hand on, or near, a stove in which a fire is burning, you know what this is. A fire always gives out heat. No matter what the fuel is, when it burns, it gives out heat.

Second, there is something that we can see. We can see the light given off by the flame. Burning coal, wood, gas, kerosene, and gasoline all burn with a flame. The color of the flame is not the same for every fuel, but there is a flame that we can see. One material that we sometimes use does not burn with a flame like the other fuels. It does, however, glow and give off light and heat. Do you know what this fuel is? It is coke, that is made from coal.

Third, the material that is burning gets smaller and smaller. Fuels such as kerosene and gasoline completely disappear. Wood and coal always contain some minerals that will not burn. These minerals are left as ashes.

Sometimes, but not always, smoke is produced when materials burn. This may happen when there is not enough air present. Unless a fuel has plenty of air, it cannot burn freely. Smoke shows that part of the fuel is not being completely burned.

But when a material burns, certain things happen which we cannot see. We cannot see them happen, but we can prove that they do happen, and we can explain them. Let us see how scientists explain what happens when fuels burn. First, how is air used in burning? You already know something about this. Air is a mixture of gases. Nearly four-fifths of the air is a gas called nitrogen, and about one-fifth is a gas called oxygen. In addition, there are some carbon dioxide, some water vapor, and a very small

The characteristics of the wood in the first picture changed greatly when the wood was burned. A chemical change has taken place.

amount of a few other gases. The table below shows you the part of the air that is made up of the different gases.

Amount of Different Gases in Air

Nitrogen	Nearly four-fifths
Oxygen	About one-fifth
Carbon dioxide	About one twenty-five hundredth
Argon	About one one-hundredth
Water vapor	Varying amounts

In *Discovering Our World, Book Two*, you learned that when the characteristics of a material change, we say there is a chemical change. In a chemical change the material changes to a different kind of material. When a piece of hard, black coal burns, only a few gray lumps are left. The characteristics of the ashes are different from those of the coal. This shows us that a chemical change has taken place.

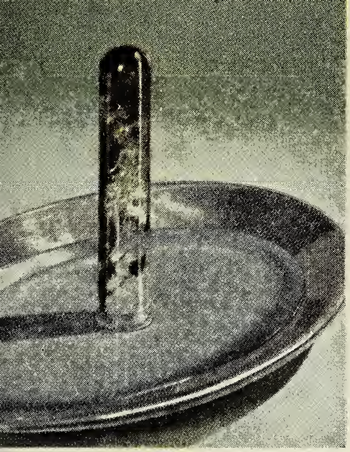
When anything burns, it unites with oxygen, and this causes a chemical change.

How do you suppose that you could find out for yourself whether materials really need oxygen from the air in order to burn? When a scientist has a problem such as this, he tries to think of some way of experimenting to find the answer.

One way of solving the problem would be to take the oxygen out of some air and then see if materials will burn in the air after the oxygen has been taken out. How can you do this? A scientist knows several ways. One of the easiest methods of taking oxygen out of the air is to let iron rust in the air. When it rusts, it changes to a soft, crumbly material because it unites with oxygen. When this happens, a chemical change takes place in the iron, and a new material takes the place of the iron.

First, get some iron filings. You can get these by filing a piece of iron. These filings are a dark gray color. Next, fill a test-tube or a small bottle full of water and then pour the water out. The sides of the test-tube will then be wet. Now pour iron filings into the test-tube and shake it. Some of the filings will stick to the sides of the tube. Then set the test-tube mouth downward in a pan of water and leave the tube until the next day. What do you expect to see when you look at the tube tomorrow?

What happened in this experiment? The iron

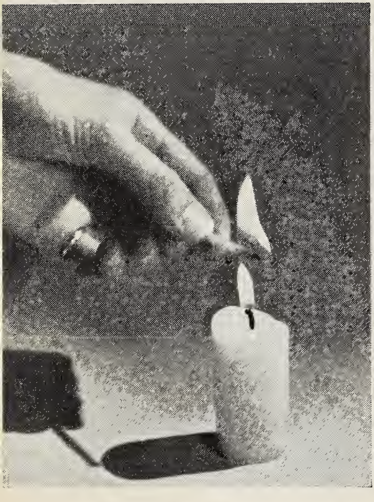


filings changed to a brownish color. This shows that they had rusted. When they rusted, they took the oxygen out of the air. Water rose in the tube to take the place of the oxygen that was removed. This happened because the outside air-pressure was greater than the pressure in the tube; therefore, the air pushed water up into the tube.

The test-tube now has no oxygen in it, and we want to find out whether materials will burn in this air from which the oxygen has been removed. Put your thumb over the end of the test-tube under the water. Then take the test-tube out of the water and turn it right side up. Keep your thumb over the open end. Now light a match, take your thumb off the tube, and immediately put the burning match down into the tube. What happens?

When you see the match go out, you may say, "Well, this proves it. There is no oxygen in the test-tube; so the match goes out. This shows that materials need oxygen when they burn." A scientist, however, is more careful than that. He says, "The match might go out because the test-tube is such a narrow place. I had better check this." What do you suppose he would do to see if the narrow space made the match go out? He would take a test-tube that had not been used in the experiment and repeat the test with a burning match in this tube. Try this to see what happens.

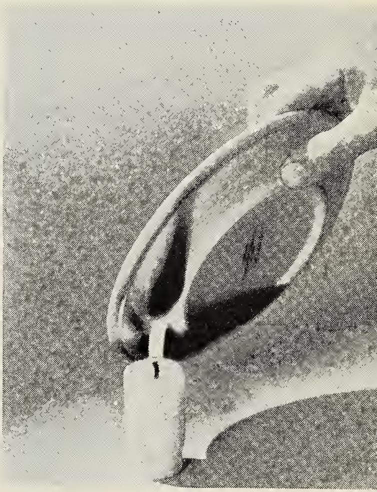
The match does not go out at once. This shows that the narrowness of the tube was not the cause that made the first match go out. The scientist is now ready to believe that oxygen is necessary to keep a match burning. He would carry on still other experiments with all sorts of burning materials to see if oxygen is necessary before he would say, "All materials need oxygen when they burn."



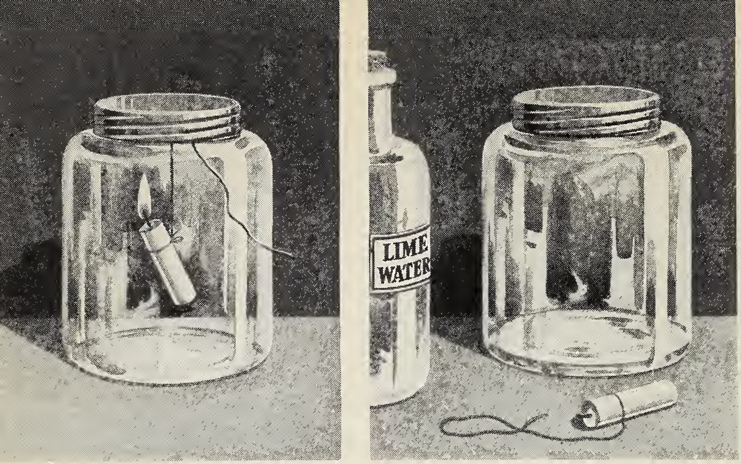
The flame was put out and the match held above the wick. The wick immediately caught fire. On the next page you will find out why.

Experiments prove that oxygen unites with all materials when they burn. Perhaps you would like to experiment to see what happens when an ordinary paraffin candle burns. Paraffin is a material made of two elements, carbon and hydrogen. Let us find what happens when a candle burns. Light a candle, and when it is burning well, blow it out. Notice that a white gas is given off at the wick for a short time after the candle is put out. Again light the candle and blow it out after it is burning well. Hold a burning match about one-half inch above the wick. What happens?

When a candle burns, the paraffin first changes into a liquid and then into a gas. This gas contains carbon and hydrogen. You can see that it contains carbon if you hold a cold saucer in the candle flame. This will cool the carbon in the flame so that it does not burn. Do you see the black, unburned carbon that collects on the under side of the saucer?



Why does the saucer become black when it is held in the candle flame? Where did the black material come from? What is it made of?



However, when the carbon in this gas burns, it unites with oxygen and makes a compound called *carbon dioxide.* Carbon dioxide is a colorless gas. You have heard of carbon dioxide many times before. It is given off from your lungs when you breathe. You can do an experiment to see whether carbon dioxide really is formed when a candle burns.

To find out, you will need some lime-water. You can get this at any drug store. Lime-water is a clear liquid, and scientists tell us that it will turn to a milky color if carbon dioxide is mixed with it. Get a glass tube or a soda straw. Put it in a glass containing a little lime-water and blow through the tube. Does the lime-water turn milky?

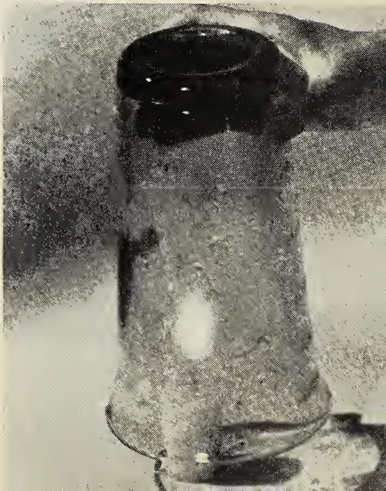
To find whether a burning candle gives off carbon dioxide, first fasten a string or a piece of wire around a candle. Light the candle and lower it into a jar.

Cover the top of the jar. When the candle goes out, slide the cover a little to one side and pull out the candle. Then quickly pour some lime-water in the jar, cover it again, and shake it. What happens?

Since there is a little carbon dioxide in air, perhaps you had better check your experiment to be sure that the carbon dioxide really came from the burning candle. To do this, pour some lime-water in a glass jar and shake it. Then you can compare the lime-water in the jar in which the candle was burned and the lime-water in a jar in which no candle was burned. What do you find when you do this?

You might try an experiment to see what happens to the hydrogen in the paraffin as it burns. When hydrogen unites with oxygen, it forms water. Is water given off when a candle burns? Let us see. Light a candle. Hold a cold glass jar mouth downward over the candle. Be sure to hold the jar so that the burning candle can get air. Look at the sides of the jar. Do you see the little film of moisture? This film that you see is water.

Because you know what happens when a candle burns, you can now see why it disappears when it



burns. The carbon in the paraffin changes to carbon dioxide by uniting with oxygen. Carbon dioxide is a colorless gas, and it quickly mixes with the air. The hydrogen changes to water by uniting with oxygen. The water is in the form of water vapor, which is also colorless. It, too, mixes with the air. You can say, then, that when a candle burns, it disappears because it changes to colorless gases as it unites with oxygen.

This picture shows waste oil being burned. There is not nearly enough oxygen in the air to unite with all the carbon in the oil. Some of the carbon makes black smoke.

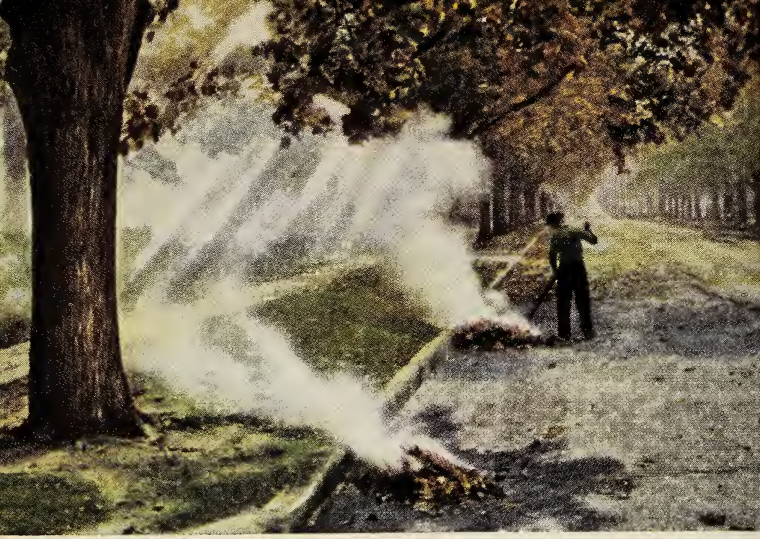
Practically all the fuels we burn contain hydrogen and carbon. When these fuels are burned, they too change into a gas that contains carbon and hydrogen, just as the candle did. This gas burns and makes carbon dioxide and water. And these fuels grow smaller or disappear when they burn. The minerals which do not unite with oxygen are left as ashes.

Sometimes fires give off smoke. This may happen because the gases are not heated to their burning temperature, or because there is not enough oxygen to unite with the gases and make them burn.

When furnace fires smoke, it is often because too much fuel is put on the fire. Then there is not enough oxygen to burn the gases that are produced. When the smoke is very black, it shows that unburned carbon is passing out into the air. You saw how this would happen when you put the cold saucer in the candle flame. Sometimes fires in stoves or furnaces make smoke because the fire is not hot enough to heat the gases to their kindling temperature. This usually happens when the fire is first started. To prevent this, avoid putting too much fuel on the fire at first.

* * *

1. How can you tell when a material is burning?
2. Why do you believe that burning is a chemical change?
3. Write down the steps you used to prove that oxygen is necessary for a material to burn.
4. How do you know that fuels which contain carbon and hydrogen change to carbon dioxide and water when they burn?
5. Why do some fuels, such as coal and wood, almost disappear when they burn? What is left? Why do these ashes not burn?
6. Why do some fuels, such as kerosene and paraffin, completely disappear when they burn?
7. Why do fires sometimes smoke? How could you keep a fire from smoking?



There are three good reasons why these piles of burning leaves are safe fires. Can you tell the three reasons?

What can you do to prevent accidental fires?

YOU REMEMBER that there are three requirements for starting a fire. First, there must be some combustible material—that is, a material that will burn. Second, the material must be heated to its kindling temperature. And third, there must be a supply of air containing oxygen. If any of these requirements is missing, a fire will not start. To prevent accidental fires from being started, it is only necessary to keep combustible materials from being heated to their kindling temperature.

There are many ways in which you can keep accidental fires from starting. One common cause of destructive fires is bonfires built by boys and girls. Everyone likes to build a bonfire, but sometimes the fire gets out of control.

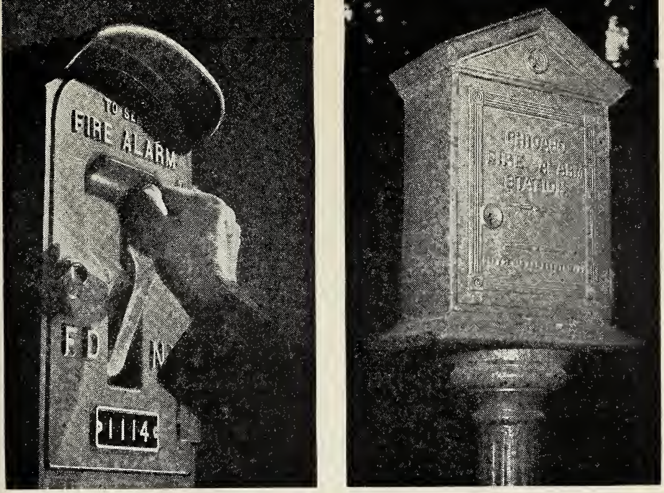
There are three things that you should remember when you build a bonfire. First, build the fire in a bare space—a place that is clear of grass and leaves. This will prevent the fire from spreading to other combustible materials. Second, do not make too large a fire. If the bonfire is too big, it will cause a strong current of air to move upward over it. Sparks or bits of burning materials may be carried upward by the draft and carried to near-by grass or buildings. Third, do not build a fire out of doors on a windy day. Sparks and other small bits of burning materials are easily scattered when the wind is blowing.

Sometimes people start fires in stoves or fireplaces with kerosene. This is a very dangerous practice. Kerosene has a very low kindling temperature. It changes quickly to a gas. Occasionally all the gas will catch on fire at the same time. When this happens, an explosion takes place. This may cause burning materials to be thrown out of the fireplace on to the carpet or rug. In stoves the doors may be blown open and burning wood or coal scattered over the room. There is really no excuse for using kerosene to start a fire. It is a lazy man's way of building a fire. Some people are too lazy to build a fire properly or are in too much of a hurry to get a fire started. A little paper and some kindling wood or corn-cobs will quickly catch fire and start larger pieces of wood or coal burning.

Occasionally fires are started by oily rags that are rolled up or thrown in a pile. To prevent this from happening, you should spread oily rags out, hang them on a line, or store them in a covered metal container. Oily rags and oily mops should also be kept in covered metal containers instead of in wooden or paper boxes.

If your house should catch fire or if you should see a fire starting somewhere, report it at once to the fire department. Do you know what number to call over the telephone? If you do not, you had better find out. Or you can report a fire by calling the telephone operator and asking her to connect you with the fire department.

If you live in a large city, you will find fire-alarm boxes every few blocks. There are different kinds of fire-alarm boxes. In some cities they are kept locked, and the key to the box is kept in the nearest house or store. In other cities you pull down a small door on the front of the box and then pull the lever all the way down and let go of it. Sometimes you break the glass front and then pull down the lever. When this lever is pulled, a signal is sounded in a central station. An alarm is then sent to the nearest



To send an alarm from a box like the one at the left, pull the lever and wait by the box until the fire truck comes. The box at the right must be opened with a key before an alarm can be sent. If there is a box like this in your neighborhood, find out where the key is kept.

fire station. You should stay near the box until the fire company arrives, so that you can tell the firemen the exact location of the fire. If you ever need to use an alarm box to report a fire, you will be in a hurry. You should therefore read the directions on the box nearest your home so that you will know exactly how to turn in an alarm.

You should never turn in an alarm unless there is a real fire. It might happen that a real fire had just started somewhere. If the fire company was answering a false alarm, the real fire might get such a big start that many buildings would be burned.

Many fires around the home could be prevented if people would only be careful. Read the following safety rules. Then look around your home to see whether all of them are followed. If they are not, what can you do about it?

SAFETY RULES TO PREVENT FIRES

1. When you strike matches, strike them away from you.

2. Close the box or the flap on a package of matches before striking a match.

3. Be sure that a match is out before you throw it away.

4. If you use kerosene or gasoline lamps, put them near the center of the table to avoid the danger of their being knocked on the floor.

5. Do not place kerosene or gasoline lamps near windows where curtains may blow into them or where they may be blown off the table.

6. Put ashes in metal containers instead of in wooden ones.

7. If an electric fuse "blows," always put in a new fuse of the proper size.

8. Do not use damaged or worn-out electric cord, because a short circuit may result.

9. Do not clean clothes inside a building with naphtha or gasoline.

10. Put out blazing fats with baking soda or a metal cover. If water is poured on burning fats, the water spreads the flame.

11. Fire-crackers and fireworks of all kinds are very

dangerous toys. They may start fires, or they may explode and burn you very badly.

12. Be careful about using flour and cornstarch on a stove with an open flame, such as a gas stove. They may explode.

* * *

1. Give a reason for each of the twelve safety rules for preventing fire.

2. Make a list of fires that you know about. What caused them? How could each have been prevented?

How can we put out fires?

FROM WHAT you know about fire, you should be able to tell three things that a person can do to put out a fire. One thing you can do is to clear away combustible materials near the fire. This will prevent the fire from spreading. Another thing you can do is to cool the burning material below its kindling temperature. A third thing you can do is to cut off the supply of air. How are these things actually done in putting out a fire?

Perhaps you have read about a large fire in some city. If a high wind is blowing and the fire gets out of control, the firemen often blow up buildings in the path of the fire. The buildings collapse into a pile of brick, covering up the combustible materials, and when the fire reaches them, there is nothing to catch

This fire lane is being made in a forest to prevent the spread of grass fires. If the grass catches fire on one side of the lane, the fire will probably not jump across the bare lane.

fire. The firemen have removed the combustible material from the path of the flames.

Perhaps you have noticed the *fire lanes* in a large forest. A fire lane is a wide path through the forest from which all trees and bushes have been cut away. This is another way of removing combustible materials from the path a fire might take. When a fire starts in the forest, it may burn until it reaches this lane. Unless the wind is strong, the fire will usually not jump across the lane. Once it is started, a forest fire is very hard to control.

Sometimes prairie fires are stopped by making *backfires*. To do this, the grass is lighted some distance

Hundreds of gallons of water are being poured on this fire every minute. Notice the great clouds of smoke pouring from the fire. Do you think the water might be causing the fire to smoke like this? Explain your answer.

in front of the advancing flame. This fire is kept under control, and is allowed to burn away enough of the grass to form a wide burned place. When the main fire reaches the burned place, it usually stops because there are no combustible materials.

Of course, the most common way to put out a fire is to throw water on it. Do you know what the water does? The water covers the burning material and shuts off the supply of oxygen. When this happens, the fire goes out. Water also helps put out the fire because it cools the materials to below their kindling temperature. Small fires are put out easily by water. To put out large fires thousands of gallons of water

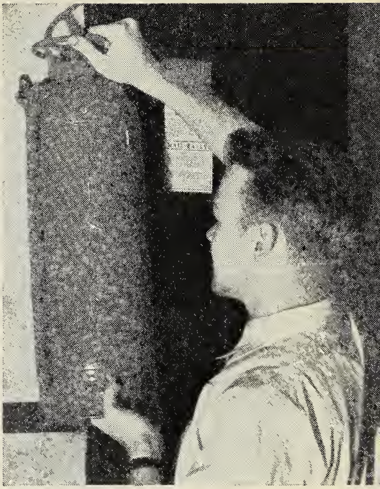
This man is using a carbon tetrachloride extinguisher to put out the fire in his car. Notice that he is aiming the extinguisher at the bottom of the flame. That is where the burning is taking place.

must be used. Water is a good fire-extinguisher because it can do two things to the fire: It can cut off the supply of oxygen and cool the materials below the kindling temperature.

Believe it or not, there are some fires that are spread by water. If gasoline or kerosene catches fire, water will just spread the fire. Do you know why this happens? Gasoline and kerosene are lighter than water; therefore they float on top of the water. Water will not shut off the oxygen supply in a kerosene or a gasoline fire. It spreads the fire because it helps to float these lighter liquids. *Never pour water on a kerosene or a gasoline fire.*

There are two ways to put out a kerosene or a gasoline fire. One way is to throw sand or soil on the fire. This cuts off the oxygen supply. Another way is to use a fire-extinguisher that contains a chemical called *carbon tetrachloride.* This chemical changes to a gas when it gets hot. This gas is about five times as heavy as air; so it settles, covers the fire, and keeps away the air. Many people carry these extinguishers in their automobiles.

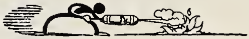
You probably have some carbon-dioxide fire-extinguishers in your school. You learned about these fire-extinguishers in *Discovering Our World, Book Two,* page 228. When this extinguisher is turned upside down, an acid mixes with a chemical dissolved in the water. This makes carbon-dioxide gas. The carbon-dioxide gas forces the water out on the fire. Then the gas settles on the fire and helps cut off the supply of oxygen. The water also helps put out



To use this carbon-dioxide fire-extinguisher, the boy will turn it upside down. Then both carbon-dioxide gas and water will rush out through the hose and help put out the fire.

the fire. Of course, a carbon-dioxide fire-extinguisher cannot be used to put out a gasoline or a kerosene fire.

From what you have learned, you should know what to do if your clothes or those of a friend catch fire. If a coat, a blanket, a rug, or any woolen article is near, lie down and roll up as tightly as possible in it. This will cut off the air. If nothing of this sort is near, the best thing to do is to lie on the ground and roll over slowly, at the same time beating the flames with your hands. The worst thing you could possibly do would be to run for help. To do so is just like fanning a blaze. It brings more air near your burning clothes and makes them burn faster.



1. What three things are needed to make a fire burn?
2. How does water put out a fire?
3. For what kind of fire should water not be used? How would you put out a fire of this kind?
4. What should you do if your clothes catch fire?

Questions to Answer

1. Why must the wood on a fire be loosely arranged to burn well?
2. How should the draft and damper on a furnace be regulated to get a hot fire?
3. How can a smoking lamp be fixed so that it will not smoke?

4. A kerosene stove has no ashes. Explain.

5. A piece of paper burns more rapidly when it is waved in the air than when it lies flat on the ground. Why?

6. Why does a pile of burning leaves give off much smoke when more leaves are thrown on the fire?

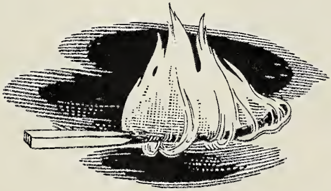
Things to Find Out

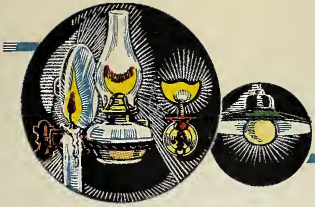
1. Make a drawing of a furnace or stove such as you use at home. Explain how the supply of air is regulated.

2. Visit your local fire station. Find out what kinds of fire-extinguishers are used.

3. Collect newspaper clippings about fires. Make a list of the causes for the fires reported.

4. Find out what kinds of roofing materials are not combustible. Why are these better than wooden roofs?





UNIT SIX

HOW DO WE USE LIGHT?

SUPPOSE you play this trick on one of your friends. Put a nickel in a metal pan when your friend is not looking, and have him stand just far enough away so that the side of the pan will keep him from seeing the coin. Then say to him, "I am going to make money right before your eyes!" Slowly pour water into the pan. Be careful not to move the nickel. Soon your friend will say, "Why, I see a nickel already!"

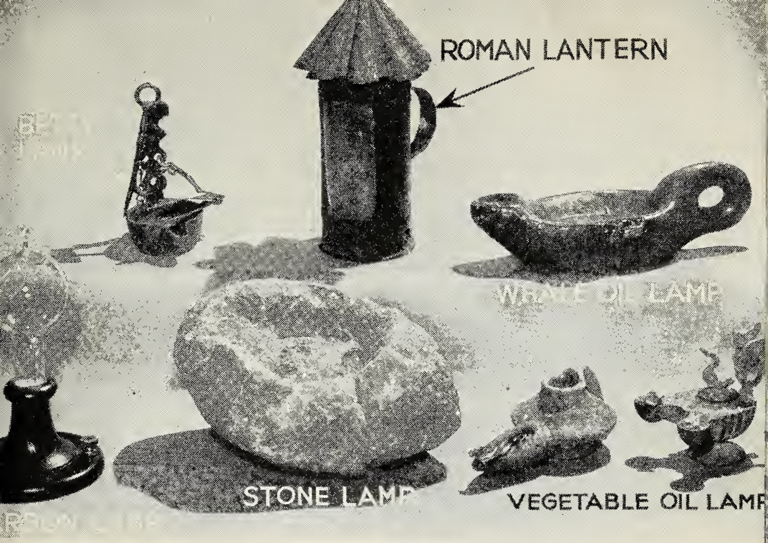
How do you explain why your friend could see the nickel when water was poured into the pan but could not see it before? Would you know what he meant if he said, "Oh, it's the light that does it"? Do you know why a stick looks bent if you hold part of it in water? Do you know that light moves and that it can bounce like a ball? Do you know what makes things have color? These are some of the questions that you can answer by studying this unit and by doing the experiments. There are many other questions, too, that you will be able to answer when you have completed your study of the unit.

How have people made light?

THE SUN is a big lamp that is always giving light to some part of the earth. Fortunately for us, the sun is a lamp that never goes out. But because the earth is a ball, only the half that is turned toward the sun receives light. As the earth spins around, we have the light of day, followed by the darkness of night. When darkness falls upon the earth, we make our own light. We use electric lamps, gas lamps, or oil lamps.

Men lived on the earth a long time before they learned how to make any kind of light. They saw the light from red-hot lava that was pouring from volcanoes, and they saw the night lighted up by trees that had burst into flame when they were struck by lightning. At first, men were afraid of fire, and they fled from it in terror. But after a while they learned to use it. And what a blessing it must have been! Now the long dark nights were more comfortable and much safer. When the warm sun sank below the horizon, roaring fires warmed these half-naked people, gave them light, and frightened away savage beasts that might attack them.

Soon these early people learned to pull a burning stick from the fire and use it as a torch. Then they could carry a light with them when they wanted to go down to the stream or lake for a drink or when they wanted to go to some other part of their cave



All but two of these old lamps burned liquid oil. The hollowed stone lamp, which may be 80,000 years old, burned oil without using a wick. At the right of the stone are two oil lamps that used a simple wick for burning the oil. Above them in the top row is a whale oil lamp. Oil lamps like this one and the "Betty" lamp are only about 150 years old. The Roman "family" lantern burned a candle instead of oil. In the bottom row is one of Edison's early carbon lamps.

home. They used several kinds of wood to make their torches, and they found that pine knots made a brighter blaze than other kinds. They also discovered that sticks and reeds would make a better light if they were smeared with grease.

After many centuries men learned how to get oil from certain kinds of plants and animals. They put oil in a hollowed stone, a sea shell, an animal skull, or a little clay dish, and set fire to it to make a light. Of course, the oil burned up quite rapidly. After a time, men thought up a real improvement: They put a wick in the oil and lighted the wick. This crude lamp made a better light, and it would burn longer. Also, it could be regulated by using a big wick or a little wick. If you could visit an Eskimo igloo today, you would probably find it lighted by a little dish of whale oil with a wick made of reindeer moss.

Candles are usually made by pouring melted wax in molds, but this California candle-maker has his own way of working. Each day he pours a little more wax over the candles to make them larger and larger.

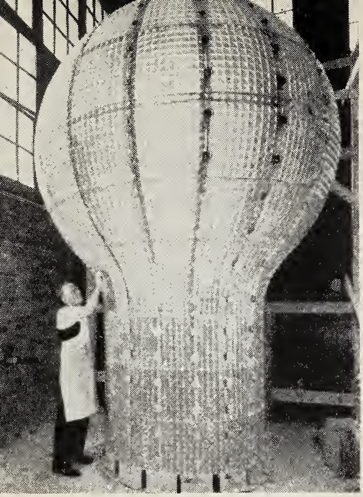
The next great improvement in lighting came when people learned to make candles by pouring hot wax around a wick. When the wax cooled, it hardened. These candles were much better than dishes of oil because they could be easily carried around.

About eighty years ago an exciting discovery was made in northwestern Pennsylvania. A tremendous supply of thick, black oil was found deep down in the earth. From this oil people made kerosene. Kerosene was then burned in lamps with chimneys, and it gave a much better light than candles. However, the light was still far from good; and it was quite a nuisance to fill the lamp with kerosene, trim the wick so that it would burn evenly, and wash the lamp chimney almost every day. So the hunt for a good light went on.

Scientists had been experimenting with a kind of gas that comes from coal when coal is heated. This gas burned easily, and soon special kinds of lamps were invented to use this burning gas for light. Before long, the gas was being manufactured for entire cities to use. Then large amounts of almost the same gas were found underground when men drilled down for oil. This *natural gas*, as it was called, was piped to cities and furnished homes with a cheaper and better material to burn for light than people had ever known.

All this time, you see, light was made by burning something. Wood, oil, kerosene, and gas were the materials that were burned. But when a material burns, it is soon all used up. Then you must get more material before you can have a light again. If men could only find some way of making light without burning a material!

Can you think of any way to make light without burning up the material you are using? You know



This big glass bulb has been placed at the top of a tall tower in Menlo Park, New Jersey, where Edison had his laboratory and invented the first electric lamp. It is 14 feet high and contains more than 6000 pounds of glass. It is lighted by powerful lights inside it, so that it can be seen for a distance of many miles.

that electricity can make light by heating a wire or a gas until it glows. Neither the wire nor the gas is burned up. It will give light for weeks and months. It can be cooled and heated and cooled and heated many hundreds of times before it finally wears out. When Thomas A. Edison invented the first electric lamp, about sixty years ago, he discovered the best way of making light that the world had ever known.

* * *

1. What different ways have people used to light their homes?
2. Name the discoveries that helped people to have better light.
3. How is an electric lamp different from a kerosene lamp or a candle?
4. Why would you rather have your home lighted by electricity than by kerosene?

How does light travel?

At about the time the first settlers were coming to America, there lived in Italy one of the greatest thinkers the world has ever known. His name was Galileo. One day Galileo was thinking about light, and this question came to him: "If someone lights a lamp far away from me, do I see the light instantly, or does it take a little time for the light to reach me?" Now one of the reasons Galileo was so great was that he experimented to get facts. He did not just guess, or try to think without facts.

To answer his question about light, Galileo worked out an experiment. He sent some men up on a high hill with a lantern that had shutters on it. These shutters could be opened and closed quickly. Galileo then went up on another hill several miles away with another lantern. Before his helpers went, he said to them, "As soon as you see me flash my light, you flash yours. Maybe I can figure out how long it took you to see my light, and then for me to see yours." Of course this simple experiment could not tell Galileo what he wanted to know. It could not be accurate, because it took Galileo's helpers a second or two to open the shutters of their lamps.

But Galileo was on the right track when he believed that light moves and that it takes time for it to move. Not long after this a Danish astronomer figured that light travels at the unbelievable speed of about 186,000 miles a second. Few people, however, believed him. Just a few years ago an experiment was performed which was quite like the one that was done by Galileo. This time, however, special apparatus was built to flash the light and record the time that it took to travel to a distant mountain and back. This experiment showed that light travels at the speed of 186,284 miles a second. Scientists tell us that nothing travels faster than light.

If you could have watched Galileo's experiment, you would have seen something like this.

Sound, you remember, travels about 1100 feet a second through air. Light, then, travels nearly a million times as fast as sound. This explains why you hear the thunder after you see the lightning. The light of the flash travels much more rapidly than the sound of the thunder. All light, whether it comes from the sun, from lightning, from the electric light in your room, or from a tiny candle, travels at this same terrific speed.

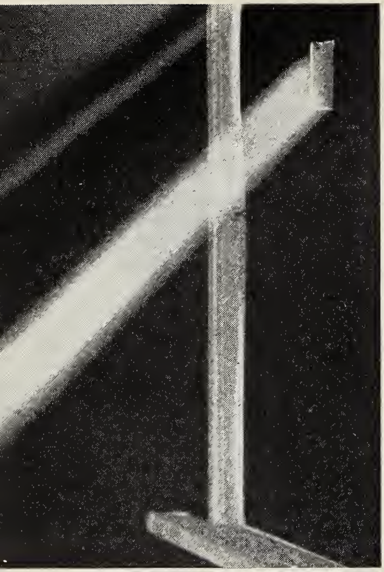
In the time it takes you to wink an eye, light can travel fast enough to go around the earth almost eight times. But light cannot go around the earth. If it could, the whole earth would always be lighted.

Try this experiment and you will understand why the sun's light cannot travel around the earth. Do the experiment in a dark room. Get a ball and a small light. A flash-light will do. Hold the flash-light near the ball. One side of the ball is brightly lighted. Is the other side lighted in the same way? The other side is in a shadow. It is not receiving any direct light from the flash-light. The light is not curving around the ball.

The ball is lighted only on one side. What does this picture tell you about how light travels?

Perhaps you can discover for yourself how light travels if you try several experiments. Get a big piece of brown wrapping paper large enough to cover a window through which the sun is shining. Then cut a hole about an inch square in the paper and pin the paper over the window. Darken the room as much as you can. Then look at the light streaming through. If you cannot see the light very plainly, put some chalk dust from erasers in the path of light. Is the light traveling in a *straight line?*

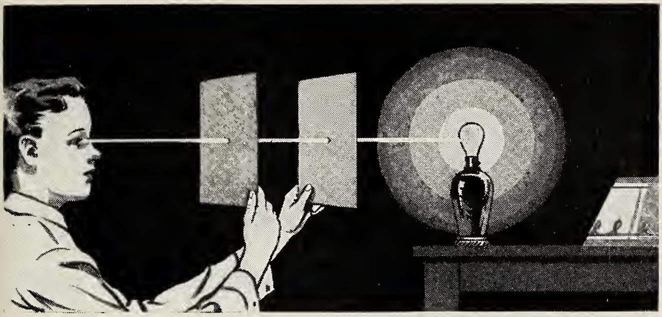
Try this experiment, also. Get two pieces of cardboard and punch a small hole in the center of each. Take one of the cardboards in each hand. Hold both cardboards between your eye and a lighted electric lamp so that you can see the light through the holes. Now move one cardboard a little to the right. Can you see the light now? Does this seem to show that light travels in a straight line?



Have you seen sunlight coming in at the side of a drawn shade or through a hole in it? Can you tell from this how light travels?

Hold a book so that the sunlight is falling directly on it. Why does the book make a shadow? The light cannot go through it, and it cannot go around it. If the light could go around the book, there would be no shadow. This is another way of seeing that light travels in a straight line.

In the experiments with the cardboards and the



The white line shows how light travels to your eye through the holes in the cardboards.

book you found how light travels through one material—the air. But you do not know how light acts when it passes from one material to another. For example, you do not know how light travels when it passes from air into water or into glass. So you must say: Light travels in a straight line when it passes through the same material. Later in the unit you will learn how light acts when it passes from one material into another.

There is another interesting fact about the way light travels. When you light a lamp, turn on an electric light, or hold up a flaming torch, light travels out in all directions. Things below the lamp, above the lamp, and all around the lamp are lighted by it. This is true because light travels in all directions from any glowing material—up, down, and out from all sides. Think how valuable this is to us. One lamp can light all parts of a room—floor, ceiling and walls.

1. Give a reason why Galileo's experiment could not show him how fast light travels.

2. Which of the following sentences are true?
a) All light moves.
b) Sunlight moves faster than candlelight.
c) Light travels faster than sound.
d) Light travels in a straight path through air.
e) Light curves around the earth.

3. How fast does light travel?

4. What three important facts have you learned about how light travels?

5. Why do you see something happen at the moment it happens?

What happens when light strikes materials?

Did you ever make shadow pictures against the wall or against a white sheet? When you do this, where must the light be? It must be back of your hands; that is, your hands must be between the light and the sheet so that your hands "throw a shadow" on the wall or the sheet. There is a black spot, or a shadow, on the wall because the light cannot travel through your hands. When you see the shadow of an object, you know that light cannot travel around this object or through it.

But you see that light does pass through some things. You cannot make a dark shadow with a piece of clear glass or with a sheet of cellophane because light passes through these materials. When so much light passes through a material that you can see objects on the other side of it, the material is called *transparent*. Air is transparent. Can you name some other transparent materials?

The window-glass through which this child is looking is transparent. However, rain is running down the window and makes streaks on the pane that are less transparent than the glass.

But what happens to light when it strikes a material that it cannot pass through? Does the light stop? What becomes of it? Get a mirror and watch what happens when light strikes it. Hold the mirror so that direct light from the sun strikes it. Does it throw a spot of light to the wall or ceiling? The mirror is like a ball player. The mirror "catches" the light and "throws" it to the wall. Also put a pan of water in the sunlight and watch it throw a spot of light. Sunlight strikes the water and is thrown to the ceiling.

We use the word *reflect* instead of using the word "throw" when we are talking about light. We saw that the mirror and the pan of water reflect light. Any highly polished material will reflect light almost as well as the looking-glass does. Often mirrors are made by polishing a piece of metal.

This automobile has been polished so bright that it makes a fine mirror for Dick! What other surfaces can you name that make good mirrors?

Do objects such as soil, rocks, clothing, carpets, and walls reflect light too? Look again at the pan of water that is reflecting the bright spot of light to the ceiling. Notice how smooth the top of the water is. Now stir up the water so that its surface is rough. What happened to the spot of light? The light was scattered. The rough surface of the water reflected the light in different directions. Therefore no bright spot was seen. When the surface of the water was smooth, it reflected the light all in one direction and made a bright spot. But when the surface of the water was rough, the light was reflected in different directions. Because this scattered the light there was no bright spot.

Now get a blotter and a piece of glossy cardboard. Look at the surface of each of these with a magnifying glass. Which one is smoother? The smooth cardboard looks shiny, and the uneven blotter looks dull. Both shiny and dull objects reflect light. When light strikes an object, only part of the light is reflected. The object keeps part of the light. We say that the object *absorbs* part of the light. Dull, rough materials absorb more light than shiny, smooth ones.

Such materials as soil, clothing, and carpets reflect light, but they appear dull for two reasons. First, they have rough surfaces which reflect light in all directions. Second, they absorb much of the light that strikes them.

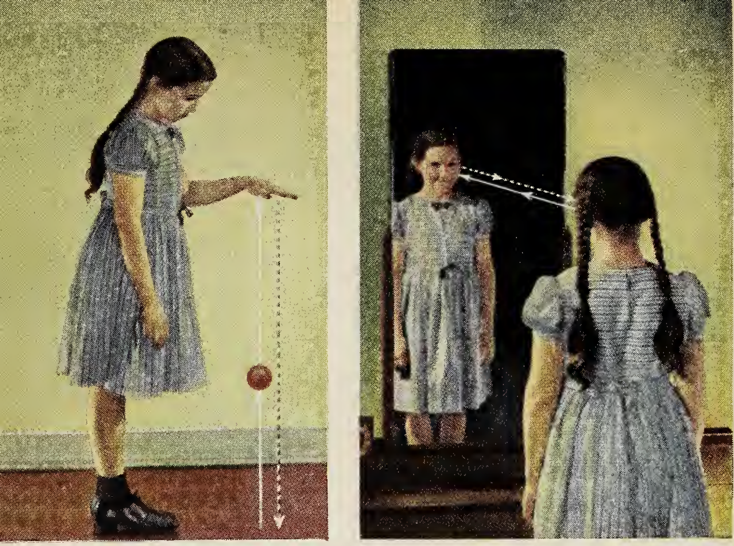
1. What do the following words mean?
transparent *reflect* *absorb*

2. Tell two reasons why a material may look dull.

3. Why will a dirty mirror reflect less light than a clean one?

4. Tell three things that may happen to light when it strikes an object.

5. Why is a wet pavement more shiny than a dry one?

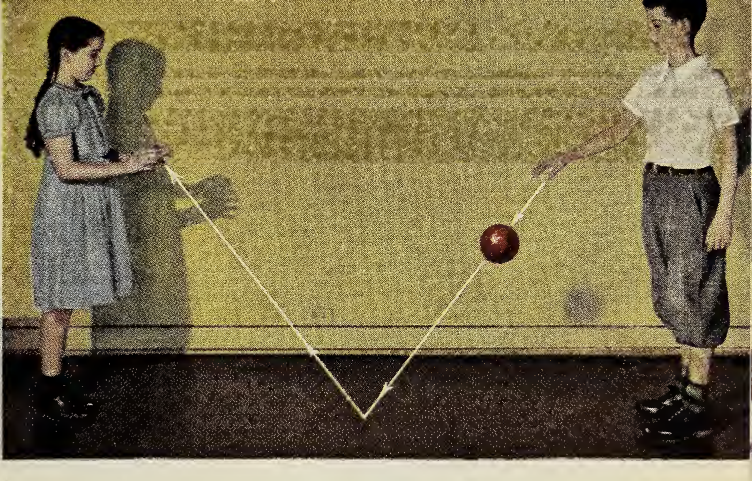


The ball falls straight to the floor and bounces straight back to the girl's hand. The light travels straight to the mirror and straight back to the girl's eyes.

Why do you "see yourself" in a mirror?

THINGS THAT reflect light, as you have learned, seem to be "playing ball" with light. But a mirror has its own rules for playing the game with light. Let us see just how a mirror plays "bouncing the ball" with light.

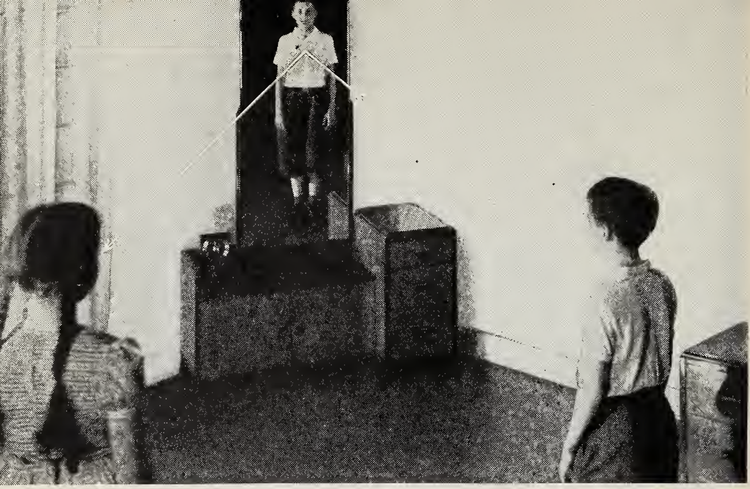
Bounce a rubber ball on the floor. Notice that when you throw the ball straight down, it bounces straight back up toward your hands, so that you can catch it. Now stand in front of a mirror. You are throwing light straight at it. Light from the sun or from a lamp is striking you and is being reflected straight



How are the ball and the light alike in this picture and in the one on the next page?

into the mirror. The mirror throws the light straight back to you, just as the ball bounced straight up to you. You could catch the ball. Your eyes can "catch" the light, and you can see yourself in the mirror.

But what happens if you throw the ball to the floor at a slant? It bounces away from you, and you cannot catch it. Suppose, then, that a boy and a girl in your class bounce the ball from one to the other. When the boy bounces the ball at a slant, where does it go? It bounces toward the girl, and she catches it. Watch the ball very carefully while the boy and girl are bouncing it. It travels toward the floor at a slant. Does it travel toward the catcher at a slant, too? Is the slant about the same both times?



To take this picture the camera was placed near the girl. The picture, therefore, shows what the girl saw in the mirror. The light that strikes the boy is "thrown" to the mirror at a slant, and the mirror "bounces" it to the girl at the same slant. If the camera had been placed near the boy, whose picture would you have seen in the mirror?

If you stand at one side of the mirror, light will travel from you to the mirror at a slant. Does the light "bounce back" to you? You know that it does not bounce back to you because you cannot "see yourself." Where does the mirror throw the light?

To find out where the light is thrown, have a girl and a boy stand each a little to one side of a mirror, so that the girl cannot see herself in the mirror and the boy cannot see himself. But what does the boy see? He sees the girl! Light travels from the girl to the mirror at a slant; then the light bounces toward the boy at the same slant. The boy can then see the girl. What does the girl see in the mirror? Can you explain why?

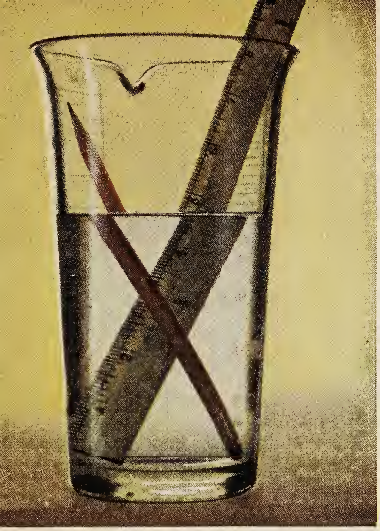
When you stand in front of the mirror, light travels straight to it from you and straight back to you again. Therefore you can "see yourself." But when you are at one side of the mirror, the mirror catches the light from you at a slant. The mirror then throws the light in the opposite direction at the same slant. You say that you "see yourself in the mirror," but of course you are not "in" the mirror. You are standing in front of the mirror. What you see in the mirror is your *reflection*. Light strikes you, is reflected to the mirror, and is reflected back to you. You have seen reflections of trees and clouds in streams and lakes.

* * *

1. Where do you stand if you wish to see your reflection in a mirror? Why?
2. How is your shadow different from your reflection in a mirror?

What happens when light passes from one transparent material to another?

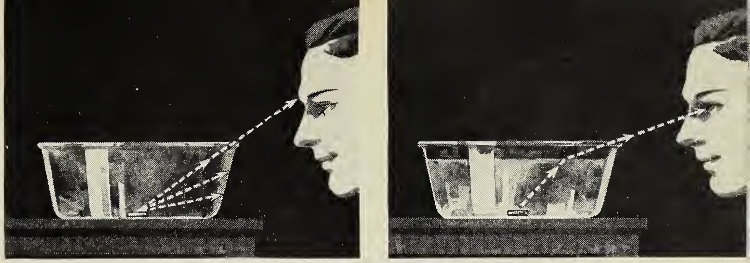
Here is an experiment that will show you a strange thing about the way light travels from one transparent material to another. Put a pencil in a glass of water. Rest the pencil against the rim of



the glass so that it will be slanting in the water. Now if you look at the pencil, you will see that something interesting seems to have happened. You are sure that nothing really has happened to the pencil, but it seems bent. Can you tell why it seems to be bent? The next paragraph will tell you how scientists explain it.

Scientists say that light travels in a straight line while it is passing through the same material. But they also tell us that light is bent when it travels at a slant from one transparent material to another. In this experiment the transparent materials are air and water. Part of the slanting pencil is in the water. Light travels from this part of the pencil to the top of the water. Then, as it passes from the water to the air on a slant, the light is bent. This makes the pencil look as if it were bent.

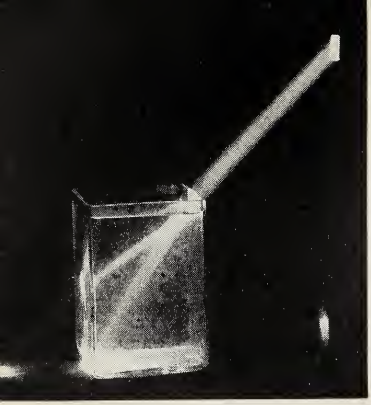
In the trick described on page 229, have you any idea why your friend could see the coin after the water was poured into the pan? Before you poured in the water, the light that was reflected from the coin traveled only through air. Since it traveled in a



In the first picture light from the coin travels through the air in a straight line. Some of the light rays strike the sides of the pan. Some of them go out over the edge. But those that go out are traveling too high to reach the boy's eyes, and so he cannot see the coin. In the second picture light rays from the coin are bent downward as they go from the water to the air. So now they go low enough to reach the boy's eyes, and he can see the coin.

straight line, it did not reach your friend's eyes. The side of the pan prevented him from seeing the coin. But with water in the pan, the light traveled from the coin first through the water and then through the air. He was looking at the water from a slant. Light traveled from the coin to the top of the water. Then, as it passed from the water to the air on a slant, the light was bent. This made the coin seem to be where it was not. Then he could see the coin.

One day Joe was fishing with several of the boys. Finally he got tired and went over to see if anyone had caught a fish. While he was gone, the end of his fishing pole fell into the water. When Joe returned, he shouted excitedly that he had a fish so big it had broken his pole. But when he pulled the pole out of the water, it was not broken, and there was no fish



When you do this experiment, see if you can split the light the way it is split in this picture. You can do so by having part of the light strike the top of the water and part strike the side of the glass. Move the jar around to see what different things you can make the light do.

on his line. Why did the pole look broken when part of it was in the water?

If you can darken a room, perhaps you can see light being bent. Fill an aquarium, or some other large glass jar, with water. Make a small hole in a big piece of cardboard. Hold a flash-light against the cardboard so that light comes through the hole and strikes the water at a slant. What happens to the light?

You have learned that light bends when it passes at a slant from one transparent material to another. You have seen that it bends when passing from water into air. Suppose you examine a magnifying glass. It, too, is a transparent material. If you feel the glass, you will notice that it is curved. The glass is thicker in the middle than it is at the edge. Because of this curving, light will enter the glass at a slant.

Now hold the glass between the sunlight and a piece of paper. First put the glass on the paper; then slowly move the glass away. Do you notice that the circle of light on the paper gets smaller and smaller as you move the glass away? Finally the large circle becomes just a point of very bright light. As light passes through the glass, it is bent inward, and finally it all comes together at a point.

Raise and lower the magnifying glass to find out how it will bend the light that passes through it.

The magnifying glass that you used is a *lens*. A lens is made of a transparent material, usually glass, and is curved on one side or on both sides. In a magnifying glass the lens is curved on both sides, and it is thicker in the middle than at the edge. This kind of lens can bend light so that objects seen through it appear larger than they really are.

Look through the side of a glass of water. Does it make things that are in it or on the opposite side of it look larger? Put your finger in the water and hold it against the far side of the glass. As you look through the water at your finger, does it seem larger? Hold an open book close behind a glass of water. Does it look larger through the glass of water? A glass of water, too, you see, is curved. Therefore it bends light in the same way that a magnifying glass bends it. Does this explain why goldfish look larger through the side of the bowl than when you look down at them through the water?

* * *

1. Choose the correct endings for this sentence: *When light passes at a slant from air into water,*
a) it travels into the water in the same straight path that it followed through the air.
b) it is bent.
c) it makes objects in the water appear to be where they are not.
d) it keeps objects in the water from being seen.

2. What is a lens?

3. What happens to light when it travels from air through a glass lens? From air through a thick drinking glass full of water? At a slant from air into water?

4. When objects are seen through a lens, why do they look different from the way they look when they are seen through a piece of window glass?

5. If you throw a rock at a fish in the water, should you aim above the fish or below the fish?

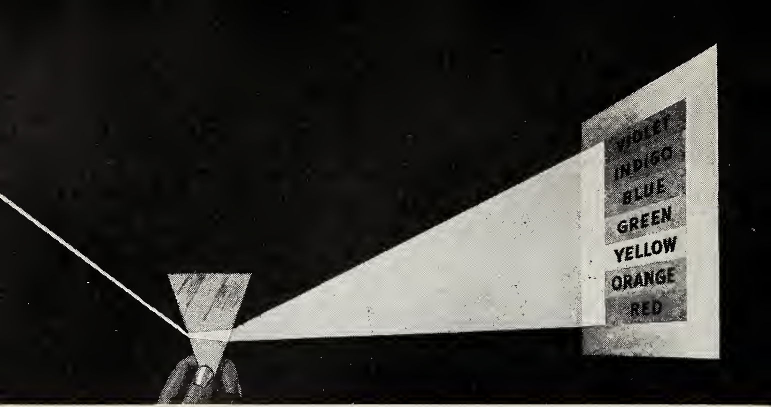
Why do objects have color?

Of course you enjoy seeing things that are beautifully colored. We all like colorful stones, green leaves, colored flowers, brilliantly colored sunsets, and colored birds and insects. But do you know how all of these things get their color? Do you have any

Isaac Newton, the great scientific discoverer, was the first person to find out what makes color. Have you ever seen sunlight shine through glass and make colors like these?

idea what causes color? Perhaps you have heard your mother say, "Why, this dress doesn't look the same color at night as it did in the daytime, when I bought it." Or perhaps when you were getting a new suit or a new dress, the salesman said, "Step over here to the window so that you can see the color better."

Surely, light must have something to do with color. Let us see what we can find out about this problem. Put a glass *prism* in the direct sunlight. Let the light that passes through the prism fall on a piece of white paper. What do you see on the paper?



The side of the glass prism is slanting, and so it bends some of the light rays more than others. You can see that the violet rays are bent much more sharply than the red rays.

Can you see red, orange, yellow, green, blue, and violet? What causes these colors? They are not painted on the paper. Shut the sunlight away from the prism. Do you still have the colors?

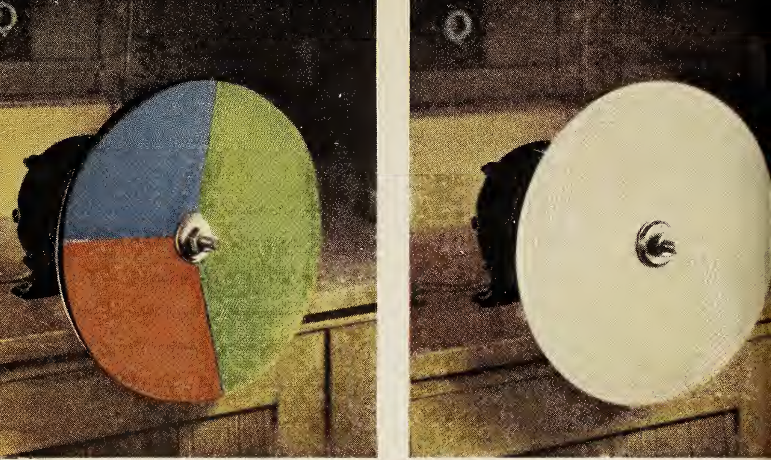
What happened to the sunlight to make these colors appear? You remember that light is bent when it passes at a slant from one transparent material into another. The sides of the prism are slanting; therefore the light strikes them at a slant and is bent as it passes through the prism.

Notice how the light is bent in the picture. The violet rays of the light are bent most. The red are bent least. Because the different parts of the sunlight are bent differently, they are separated from each other when they come out of the prism. Therefore you can see that the light of the sun is really made up of a number of colors. The light that enters the prism is white. The prism bends some parts of the light more than it bends other parts. This separates the light, and we can see the colors in it.

Where else have you seen these same colors? Of course you have seen them in a rainbow in the sky. When there is a rainbow, something must be bending the light from the sun and breaking it up into its colors. Can you tell what acts as the prism to separate the light? After a rain there are often many droplets of water in the air. When the sun shines through these drops of water, they bend the light and break it up into its colors, just as the prism does. Now when you see a rainbow in the sky, you will know that drops of water in the air are breaking the sunlight up into its colors.

Have you ever seen a rainbow when you were using a sprinkling hose? If you stand between the sun and the water, you will probably see a rainbow as the drops of water break the light up into the rainbow colors.

An experiment will help you to see that white light is really a mixture of colors. Divide a small circle of cardboard into three parts. Color each part with crayon or cut out three pieces of colored paper and paste them on the cardboard. One part must be red, one green, and one blue, in the order named. Now fasten the color-card on a top and spin the top.



You can connect your color wheel to a toy motor in this way, so that the motor will turn the wheel rapidly.

As the top spins, you cannot see each of the colors—red, green, and blue. If your top spins fast, the colors are mixed together and make a grayish white. This shows that when we mix all of the colors together, we get white.

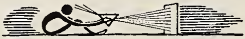
You have learned that white light is made up of several colors and that these colors can be separated from each other. But how does this explain the color of objects? You saw that each color in white light can be separated from the others by bending it away from the others. To understand why there are objects of different colors, you need to know another way in which the colors in light are separated. You remember that when light strikes an object, part of the light is absorbed and part is reflected. The cover of this book, for example, absorbs part of the light and reflects part of it. But just which part does it absorb and which part does it reflect?

Notice that the book cover is blue. It is blue because it reflects the blue part of the light! It absorbs all of the colors except blue. The blue light travels to your eyes, and the book looks blue to you. Look at a yellow pencil. The pencil reflects only the yellow part of the light; it absorbs all the other colors. A red dress reflects only the red part of the light that falls on it, an orange reflects only the orange part of the light, and green leaves reflect only the green part of the light.

The color of anything, then, really comes from the light that is reflected from it. If this seems hard to believe, perhaps this experiment will help you understand it. Make a small hole in a sheet of dark paper and hang it over a sunny window. Place a piece of white paper so that the sunlight coming through the hole falls on it. The paper is white where the sunlight falls on it. White sunlight is striking it, and it is reflected. Now hold a piece of red glass or red cellophane over the hole. What color is the spot of light on the paper? The glass lets only red light shine through it; so of course only red light can be reflected from the paper to your eyes. The spot, therefore, is red. Try using green glass and blue glass in the same way.

When white sunlight strikes the piece of white paper, the paper does not reflect just one color of the light. It reflects all the colors. This shows us that anything white reflects most of the light which strikes it.

If you look into a narrow deep hole, it looks black. You cannot see the bottom because no light is reflected from it. An object that is *really* black reflects no light. Black, then, is not a color. The only reason that you see a black object is because objects surrounding it reflect light.



1. Why does a prism make rainbow colors when sunlight strikes it?

2. Why does light shining through a piece of red glass make a red spot on white paper?

3. Explain why the cover on this book is blue.

4. Could you have a rainbow without raindrops in the air? Explain your answer.

5. Why is sunlight necessary to make a rainbow?

6. What is done to make the colors of costumes change on the stage in a theater?

7. Why does a blue dress look blue and a red dress look red?

8. A piece of cloth that is red in the sunlight will appear black if it is lighted by light shining through a green glass. Explain why this is true.

Only things that reflect light are seen in this picture. The right side of the pavement shows because it reflects light from an automobile. The glass reflectors far in the distance are good reflectors. They can reflect enough light to be seen as bright dots.

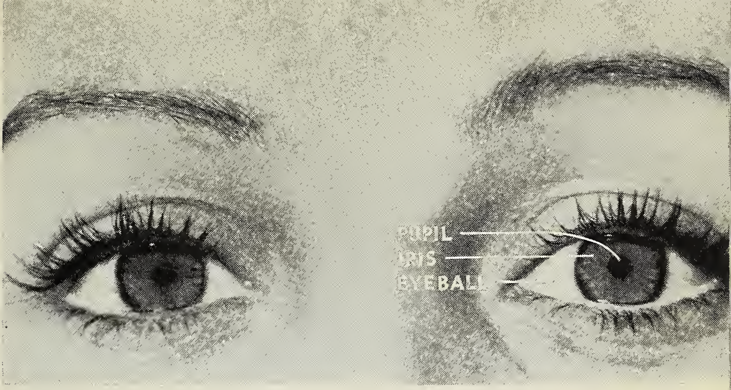
Why can we see things?

IN THE evening, as the sun is setting, it becomes more and more difficult for you to see the things around you. The light from the sun is being shut off because the earth is turning. If you go into a "pitch" dark room at night, you can see nothing, and you must feel around to find what you want. But suppose you turn on an electric lamp. You can see the lamp, because it gives off light. Why can you also see the other objects in the room? You can see them because light from the electric lamp strikes them, and they reflect some of this light to your eyes. That is the way you can see this book you are reading. The light from the sun or from a lamp is striking the book. The book reflects part of the light to your eyes, and you see the book.

Suppose you throw the light of a flash-light into a dark room. The light may clearly show a table or a chair, because the table or chair is reflecting much of the light to your eyes. You see other articles dimly. Not much light is shining on them; so of course they are not reflecting much light. Beyond them is darkness. You know that there are other objects in the room, but you cannot see them because no light is falling on them. If you look into the flash-light, you see the bulb because light is coming from the bulb. You see lighted lamps and the sun because they both give off light. You see objects either because they reflect light or because they give off their own light.

Did you ever stop to think how many things you can see? You can see very small things and very large things. You can see things near-by and far away. You can tell the color of an object, and you can see whether or not it is moving toward you or away from you. You know how important your eyes are to you, but do you know how they work so that you can see all these things?

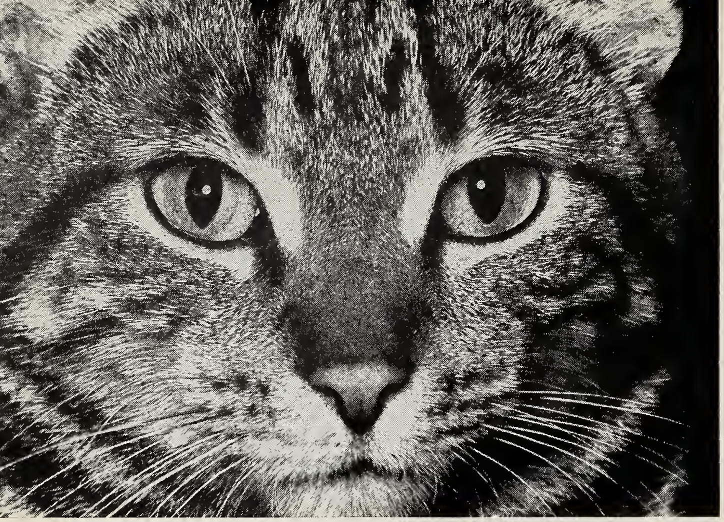
Look at the eyes of a person near you, or examine your own eyes in a mirror. Notice first the black



spot in the center of the eye. This is really a little opening, and it is called the *pupil*. The light gets into the eye through the pupil. Next examine the round, colored part that surrounds the pupil. This colored part is called the *iris*. In some eyes the iris is blue. In others it is brown or gray.

The iris changes the size of the pupil. It is like a little curtain around the opening. It can make the pupil larger or smaller. Go out into the bright light and look at your eyes in a mirror. You will find that the iris has made the pupil of your eye small. If you go into a darkened room and look at your eyes in a mirror, you will see that the pupil is much larger. When this hole is larger, it lets more light into the eye. This helps you see when the light is dim.

Now examine the white of the eye. The eye really is almost a perfect ball. It is set in a hollow place in the skull and is held there by muscles. These muscles allow the eye to move, so that we can see



Instead of being round, the pupils in a cat's eyes are slits. At night when there is very little light, the slits open wide. They let in enough light so that the cat can see in the dark.

up, or down, or to the side. Directly back of the pupil is a lens, which is thicker in the middle than at the edge. This lens bends the light that goes into your eye. The inside of the eye is covered with a lining that is very, very delicate. This lining is the part of the eye that "sees." In it are many tiny nerves that carry messages to the brain when light strikes them.

Now suppose you look at a pencil. Does light from an electric light or from the sun strike the pencil? The pencil reflects some of the light to your eyes, and the light enters your eye through the pupil. Then it goes through the lens and reaches the delicate inside lining of the eye. Here it makes a picture of the pencil on the lining at the back of the eye. This picture is carried by the nerves to your brain, and your brain tells you that the object is a pencil. There is much more to know about how we see. Sometime later in your study of science you will learn other things about your eyes and how they work.

* * *

1. What two kinds of objects do we see?
2. Why can't we see objects in a very dark room?
3. Of what use is each of the following parts of the eye?

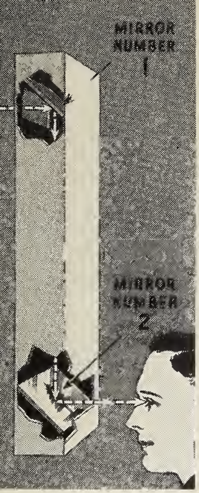
pupil	*inner lining of the eye*
iris	*muscles attached to the eye*

4. What two things do we need in order to see?

How can we help our eyes to see better?

CAN YOU see around a corner? You may think that you cannot, but scientists have invented a very interesting instrument with which you can do so. This is called a *periscope.* You can easily make a periscope by using a cardboard tube or a long cheese box. Study the picture on the next page to find out how to make a periscope. You must be careful to get the two mirrors placed at just the right slant. If you remember how light is reflected from a mirror, you can see why this is important.

In the picture on the next page the light from the

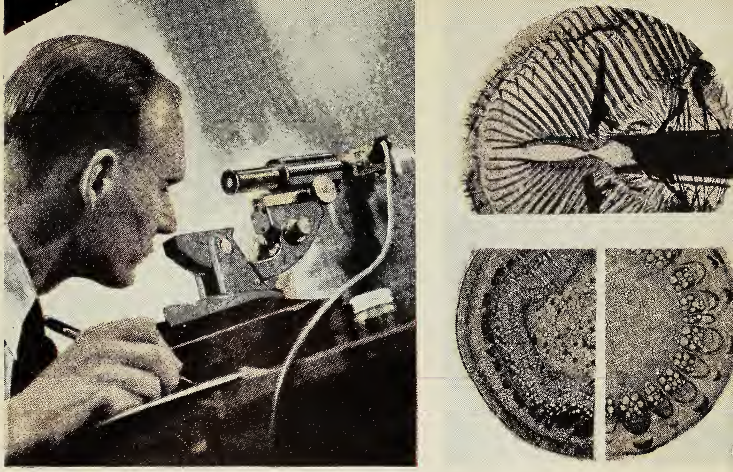


sun strikes a tree. The tree then reflects light to mirror Number 1. Mirror Number 1 reflects this light at the same slant in the opposite direction. The light then strikes mirror Number 2 and is again reflected at the same slant in the opposite direction. This time it strikes the person's eye, and he sees the tree.

A periscope is an important instrument on a submarine. When the submarine is under water, the commander can look into the mirror of the periscope and see what is going on above the water. By turning the periscope he can see in all directions.

What instrument helps us see very small things? Look at the underside of a leaf with your naked eye and then with a magnifying glass. You remember that the lens in the magnifying glass is thicker in the middle than at the edge. It makes things look larger than they really are. This kind of magnifying lens is used in a microscope. Sometimes two lenses are used in a microscope. These lenses are placed at the ends of a tube, and the tube can be lengthened or shortened so that you can see the object more clearly.

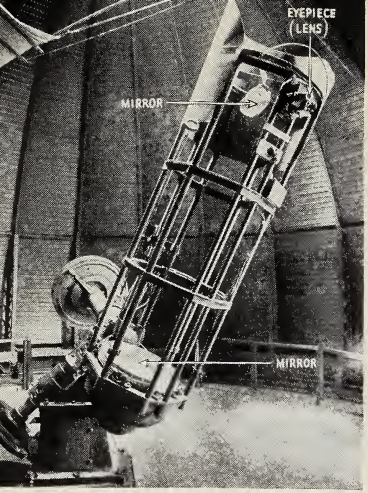
What instrument helps us to see things that are far away? You know that astronomers look at the moon, the planets, and the stars through a telescope. One of the first telescopes was made by Galileo. He



At the left a microscope is being used to study a piece of steel. At the right are some of the things you can see with a microscope. The picture at the top shows a piece of a fly's tongue, and below it you see cells in the stem of a plant.

took an old organ pipe and placed lenses in each end of it. At one end was a lens thicker in the middle than at the edge. At the other end was a lens that was thicker at the edge than in the middle. With this instrument he could see ships fifty miles out at sea. You can imagine how amazed people were when they looked through Galileo's telescope.

Sir Isaac Newton made a different kind of telescope. At one end of the tube he used a lens which was thicker in the middle than at the edge. But at the other end he put a metal mirror which was hollowed out in the center. Newton's telescope is called a *reflecting telescope*, because the light from



Here is a reflecting telescope. Light from the stars or planets falls on the mirror at the bottom and is reflected to the upper mirror. Then it goes to the lens in the eyepiece, through which a person looks.

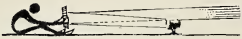
the distant objects strikes the mirror, is reflected to another mirror, and from this mirror through the lens to your eye.

These two types of telescopes are used today. One type uses two kinds of lenses; the other uses a lens and mirrors. The largest telescope in the world that uses two lenses is at the Yerkes Observatory in Wisconsin. This uses a lens forty inches across. On Mount Wilson, near Pasadena, California, is a telescope with a mirror 100 inches across. Near Mount Wilson a telescope with a mirror 200 inches across is being erected.

Have you ever looked through a pair of field-glasses at a bird up in a tree? Were you surprised at how distinctly you could see it? If you examine the field-glasses, you will see that there is a glass lens at each end of the tube and that there are two tubes, one for each eye. The tubes are really little telescopes. Each tube has lenses similar to those Galileo used in his telescope.

By using field-glasses, this boy and girl can clearly see objects that are some distance away.

Some of the boys and girls in your room are probably using glass lenses to help them read this book more easily. If the lenses in your eyes do not work properly, you can wear eye-glasses. Eye-glasses are lenses that help the eyes bend the light so that you can see objects more clearly.



1. What are the following used for? Periscope, telescope, microscope.
2. What is the important part in a magnifying glass? A telescope? A microscope? Eye-glasses?
3. Why was the discovery of the microscope and the telescope so important?
4. Why are lenses in all glasses not just alike?

What can you do to take care of your eyes?

HAVE YOU ever thought about how much of the time your eyes are at work? When you read, write, sew, work with tools, or go for a walk, a ride, or to the "movies," your eyes are always looking, looking. It is through your eyes that you learn most about this world; so it is easy to understand that they are two of your most precious possessions. It is also easy to understand how you can overwork them. Many of the other nerves and muscles in your body are at rest part of the time during the day, but not the nerves and muscles in your eyes. They are always at work, except when the eyelids close over them.

These eyes of yours are very delicate, yet they must last you a lifetime. What can you do to take care of them? Most important of all, you must be careful to use them in the best way. When they are worked too long or too hard, the muscles and nerves become tired. Then you have "eye-strain." You can strain your eyes by using them too much in a poor light. In the daytime it is easy to see out-of-doors, for sunlight is good light. But when you come indoors, the light is not so strong. If possible, you should be sure to sit near a window when you read.

At night you should have a bright light, but a shade should be placed over the light bulb to keep the light from shining into your eyes. Light from the sun or from a lamp should never shine directly into your eyes. Have you ever had a bright automobile light shine into your eyes? You probably said, "I can hardly see. The light blinds me!" Light that is reflected from highly polished or shiny things, such as the top of a table or a desk, will also dazzle your eyes if it shines into them. If the light is either too bright or too dim, it will strain your eyes. In dim light the iris cannot make the pupil large enough for you to see well. In light that is very bright, the iris cannot make the pupil small enough to keep too much light from entering.

Why is this a good light?

Can you tell why each of the following safety rules is a good rule?

SAFETY RULES FOR THE CARE OF THE EYES

1. In the daytime sit near a window when you read, sew, or do any close work.
2. At night be sure that the light shines on your work but does not shine in your eyes.
3. Avoid glare from artificial light, from sunlight, or from shiny surfaces.
4. Rest your eyes occasionally by looking away from your book.

5. When you read, sit comfortably, holding your book from fourteen to eighteen inches from your eyes.

6. Never sit facing a window or other strong light.

7. Keep your hands away from your eyes.

8. Always wear your glasses if the doctor has told you to do so. Keep your glasses clean and have them adjusted often.

9. Do not read when you are recovering from a serious illness.

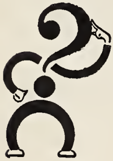
* * *

1. What two things are likely to cause eye-strain?

2. Tell how you can protect your eyes

a) from eye-strain.

b) from injury by an accident.



Questions to Answer

1. Probably you have watched a railroad train from a distance and seen a cloud of steam suddenly rise from the locomotive. A few seconds later you heard a whistle from it. The sound was made by the steam rushing out. Yet you saw the steam several seconds before you heard the whistle. Can you tell why?

2. Why can you see more clearly through a clean window than through a dirty one?

3. Would light shining through a prism of red glass make rainbow colors? Why?

4. In what way are lenses valuable to scientists?

5. Have you ever looked at something through a microscope? Tell what you saw.

Things to Find Out

1. Find out what dentist's and doctor's instruments have mirrors in them and how the mirrors are used.

2. Examine some road signs and find out why they are good reflectors. There are a number of different kinds of signs that reflect light brilliantly.

3. Find as many instruments as you can that make use of lenses.

4. Some materials seem to be one color in sunlight and another color in lamplight. Why is this true?

5. What things about your classroom help to make the light good? When you are reading or studying at home, how can you get the best light possible?

6. Try to find out how different lights affect costumes and scenery in a theater.

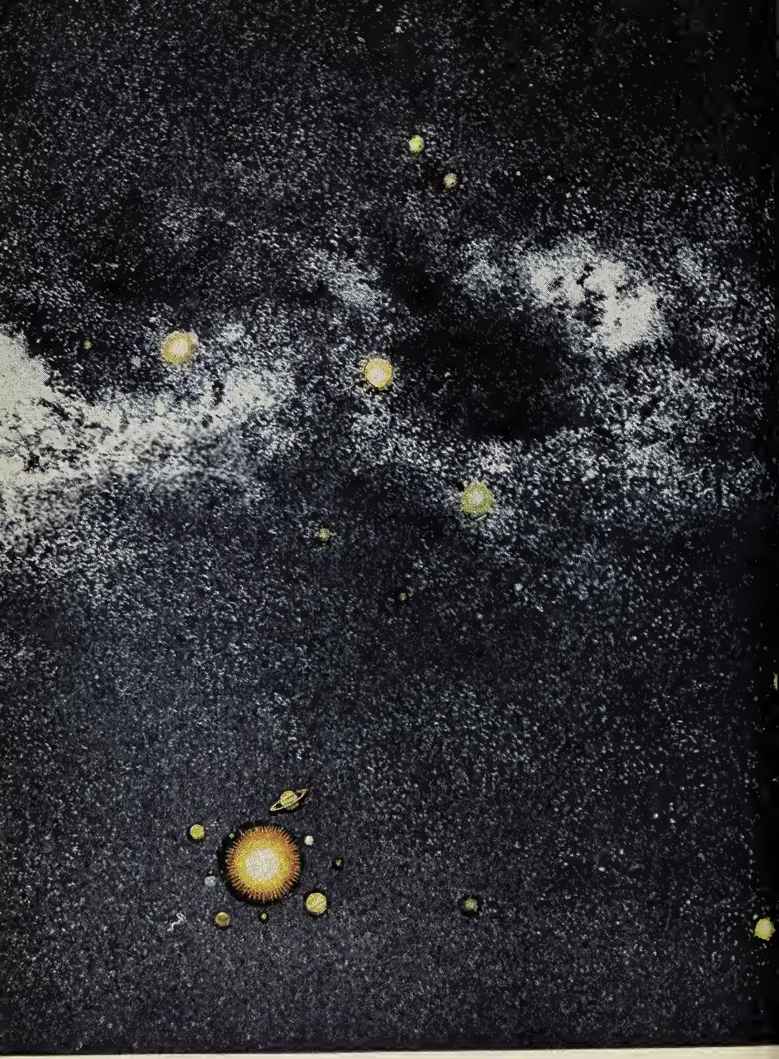
7. Examine the headlights of an automobile and find out how they throw the light ahead of the car.

8. Look for places where light is bent as it travels from one material to another.

9. Try to find out how mirrors are made.

10. Find out about the eyes of these animals: oyster, mole, fly, bird, cat, owl.

11. Blow soap bubbles and see the colors in them.



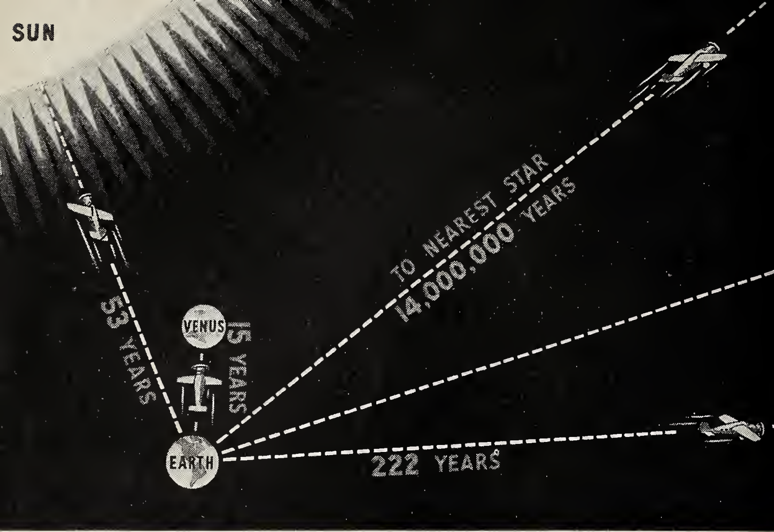
UNIT SEVEN

WHAT IS THE UNIVERSE LIKE?

When you read the title of this unit, you may have wondered what the unit is about. What does the word *universe* mean? Suppose you think of the heavenly bodies that you know. First there is the sun. Traveling around the sun are nine planets. And traveling around most of these planets are moons. There are also other bodies traveling around the sun, but we see them only occasionally. These bodies we call comets. The sun and all of the heavenly bodies traveling around it are called the *solar system.*

Far out in space, beyond the planets, we see the stars. We can see about 5000 of these stars with our naked eyes. But the telescope shows us there are actually thousands of millions of stars. Stars do not belong to our solar system. We need a name, therefore, that will stand for all the heavenly bodies. *Universe* is the name used for this purpose.

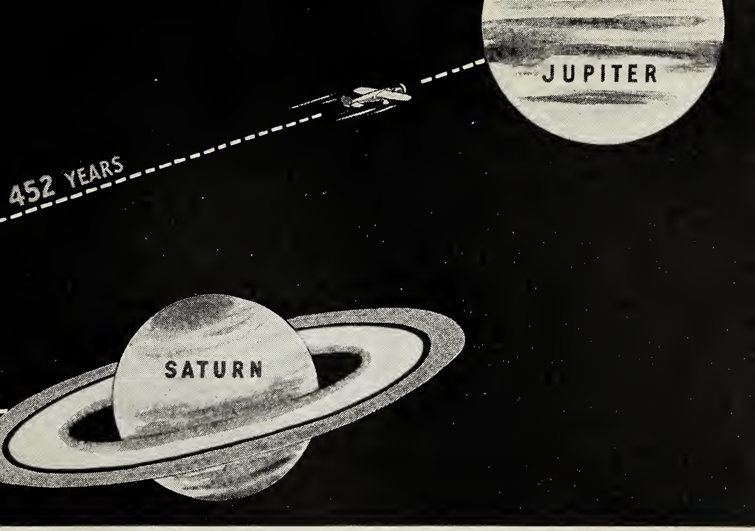
Our earth is part of the solar system. The solar system, together with the stars, makes up the universe. Now you can see that this unit is about all of these heavenly bodies.



Suppose an airplane could travel through space at 200 miles an hour, as this drawing shows. How long would it take to go to the sun, to Venus, to Saturn, to Jupiter, to the nearest star other than the sun?

How does the sun help us?

The sun is the center of the solar system. Our earth is 93 million miles from this huge ball of extremely hot gases. On a hot summer day it is hard for us to believe that we are 93 million miles from the sun. It is easy to write 93,000,000 miles; but what does this distance mean to you? It is too great for anyone to have a real idea of it. Yet this distance is small when it is compared with other distances in the universe. You will therefore need to stretch your imagination while you are studying this unit.



You could study about the many ways the sun helps us, but it would be more fun to imagine what would happen if suddenly the sun should cease to shine. What do you think would happen to us? Suppose you read this imaginary story and then try to make up one like it.

"So far as I know, I am the only one living on the earth today. Perhaps sometime in the distant future human beings may again be found on earth. I am writing this so that if the earth is ever again inhabited, people will know what became of us. I will begin at the beginning.

"It was a warm night in June, and I went to bed as usual. I woke up several times and found that it was still dark. The night seemed so very long that I finally looked at my watch. Its hands pointed to 12 o'clock. At first I thought it was midnight, but I knew I had been in bed much longer than that. Just then I heard people talking excitedly outside my window, and I quickly joined them. Everyone felt that something very terrible had happened. We knew that it must be morning; yet *there was no sun in the sky*. It will be hard for you to imagine how we felt. Just think how you would feel if you wakened some noon to find it pitch dark instead of daylight.

"We turned on the electric lights in our homes, and the city turned on the street lights. Most of us thought that we could go about our business as usual. And of course we could. We didn't notice anything very different from the day before except that there was no light from the sun. That night I went to bed again as usual. But I set my alarm clock to wake me, because there would be no sunshine to tell me that daytime had come.

"During the night it began to get colder. The next few days grew colder and colder, until we had to wear our winter coats to work. Finally we lost all track of time because there was no difference between day and night. When there had been daylight and darkness every twenty-four hours, it had been easy to tell ten o'clock in the morning from ten o'clock at night. But soon we couldn't tell the time of day or the day of the week or of the month.

Here is a field of "canned sunshine." Without sunshine there would be no wheat. What foods do you use that come from wheat?

"I had heard how the Indians kept a record of the months by means of the moon. But now there wasn't any moon to be seen. Because the sun had stopped shining, we couldn't see the moon. For the first time in my life I understood that moonlight was really reflected sunlight. The stars, though, were unusually bright and could be seen in the sky all the time.

"Although I knew that green leaves need light to make food, I was surprised to find how quickly the plants in my garden died without light. I called up the grocer and asked him to send me as many cans of green vegetables and fruits as he could. But he could sell only a few cans to each family, for soon there would be no foods to can. Never before had I realized that canned fruits and vegetables were really 'canned sunshine.'

Tell three reasons why cattle could not live without the sun. What foods do we get from cattle?

"In my garden many animals were dying because they had no green plants to eat. Several rabbits and hundreds of insects were lying dead on the ground.

"One day the milkman didn't bring the milk. The grass in the pastures had died, and the supply of hay and corn from the year before had been used up. Fortunately meat was still plentiful, but when I learned that the farmers were killing their cows because they could no longer feed them, I knew that meat, too, would soon be gone.

"Meanwhile it was getting colder and colder and colder. One day no water came when we turned on the faucet. At first I thought something was wrong with the water system, but I soon found that the water in the reservoir and pipes was frozen.

"Finally I put the last of my coal in the furnace.

As I shoveled it in, I thought, 'I am using another kind of canned sunshine.' Because, after all, that is what coal is. It is what is left of millions of plants that grew in the sunshine millions of years ago. When my coal was gone, I shut up most of the house and moved to the kitchen. I still had gas and electricity, but how long these would last I did not know. I had already been warned to use as little electricity as possible, for the only way now to make it was to use coal. And with so much coal being used, the supply, I knew, would soon be gone. Water power could no longer be used to make electricity, because all the water in the streams was frozen.

"Since the trains had stopped running and the radio and telephone were silent, we had no means of knowing what was going on in the rest of the world. Perhaps we were worse off than people in other places on the earth. Perhaps there was still some part of the world where life was going on as usual.

"As I thought of these things, I was glad that I had spent my spare time in learning how to fly. At least I could try to escape from the sure death that awaited me at home. This seemed easy until I started to leave the ground. I hadn't realized how much I depended upon light in getting off the ground. This time I had only the sense of touch to guide me. How I managed to get into the air I will never know. I couldn't see the earth below, of course. There were neither beacon lights nor city lights. I had only the friendly stars to guide me. The North Star pointed out which direction was north, and I headed my plane toward the east.

"When, after a long flight, I heard my engine sputter, I knew that I must land. I let loose a flare, and luckily saw a bare field below me where I could land. I also saw by the light of the flare a small town near by. After I had landed, I took my flash-light and went to the town. Not a living thing greeted me. I shouted and called in vain. Then the terrible thought came to me that I was probably the only human being left alive on earth. I looked for some fuel, but I could find none. I looked for food, and there was none. My fingers are so cold that I can write no more; so - - - - - - ."

Of course you know that this is not a true story. And you know, too, that the sun will not cease to shine. Astronomers tell us that the sun will continue to give off light and heat for millions and millions and millions of years. But this story may help you see in how many ways we need the sun. We would have no light, no heat, and no food without the sun. There could be no living thing on the earth without the light and heat from the sun.

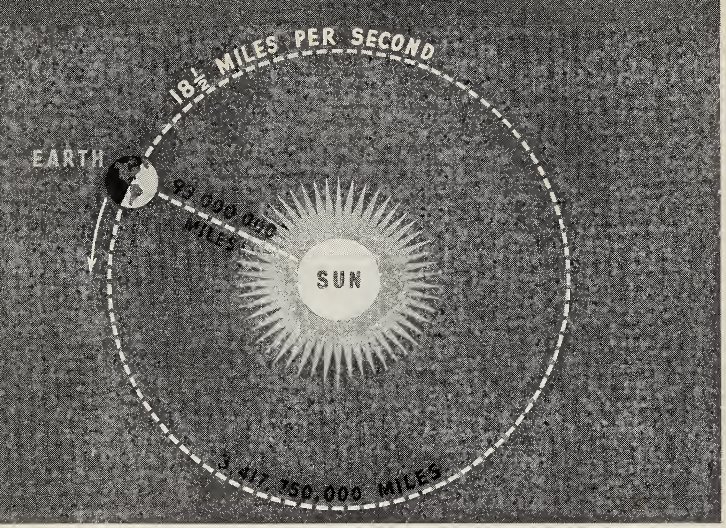
Most of the work of the world is done by some kind of power made by the sun. There would be no wind power if the sun did not heat the earth and the air

Many people of long ago worshiped the sun, and certain Indian tribes still do. The picture shows Indians of the southwestern United States in a dance of thanks to the sun.

around it. There would be no water power if all the water were frozen. The power stored up in coal came from plants that grew in the sun ages and ages ago. It is no wonder that the peoples of long ago worshiped the sun. They, too, knew how much it meant to them and to everything on the earth.

* * *

1. Name as many ways as you can in which the earth without light or heat, as told about in the story, was different from the earth as it really is.
2. How does the sun help us keep track of time?
3. Make a long list of ways the sun helps us.



What is the solar system?

Have you been in an automobile, an airplane, or a train when it was going very, very fast! How fast have you ever gone? Did you ever go 60 miles an hour in an automobile, or 80 miles an hour on a train, or 200 miles an hour in an airplane?

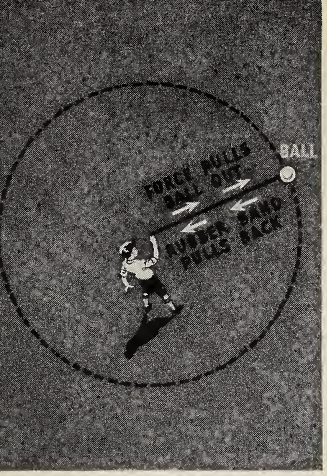
You may think such speeds are fast, but as you sit quietly at your desk, reading this page, you are traveling 66,000 miles every hour! Every second you are whizzing 18½ miles through space. In the time it takes you to count 10, you will have gone almost 200 miles. Yes, the earth is going at that terrific speed as it travels around the sun. And yet you need not be afraid of falling off the earth. A great force called gravity holds you on. You cannot jump off the earth, even if you try. You can jump up into the air a few feet, but gravity pulls you right down again.

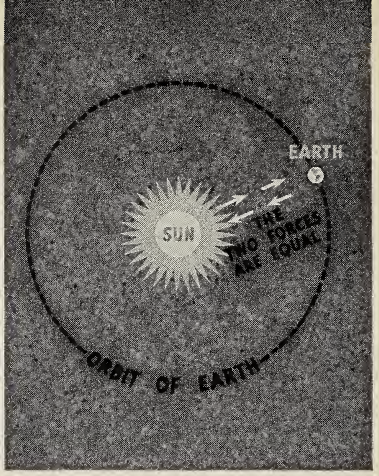
Perhaps you are wondering why you do not feel this tremendous speed. When you are traveling fast in an automobile or a train, you can see trees, telephone poles, and houses pass quickly by your window. You learn to tell how fast you are going by seeing how fast you pass nearby objects. But there is nothing near the earth to tell you how fast the earth is moving. Our nearest neighbor, the moon, is 240,000 miles away. We do not realize we are moving, because we cannot see that we are passing anything.

With the aid of a pole this athlete can get fourteen feet or more off the ground. But the force of gravity immediately pulls him back to earth again.

You need not be afraid of the earth's great speed. The earth keeps in its same path and will not crash into anything. Every year we take the same long journey around the sun. Year after year we travel in the same path at the same speed.

If you try an experiment, you will find why the earth keeps rolling along in the same path. Get a ball and attach a strong rubber band to it. Now whirl the





ball round and round over your head. The harder you whirl, the farther out the ball goes, until finally it will go no farther. Notice that when it is going at the same speed, the ball stays in the same path and keeps the same distance from your head.

When you whirl the ball, there is a force that pulls the ball away from your hand. At the same time the rubber band is pulling the ball in toward your hand. So there are two forces, one pulling the ball out and one pulling it in. The ball will move out no farther when the pull of the rubber band on the ball is just equal to the force that pulls the ball out. It will stay whirling in this path.

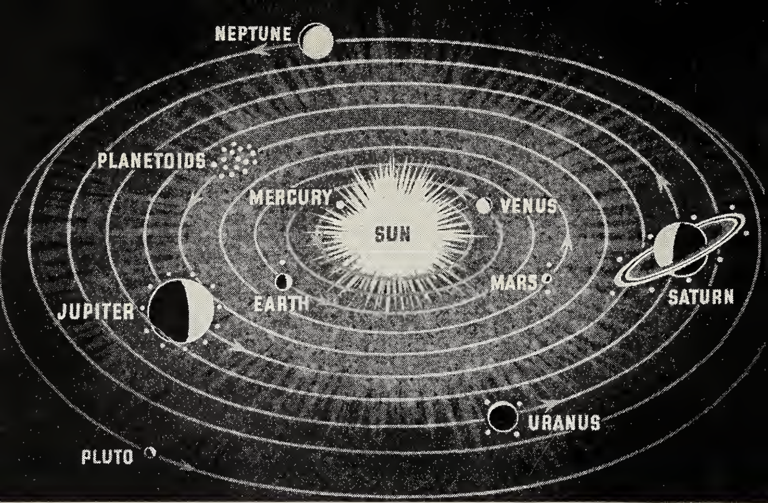
Now let us see how the whirling ball helps us explain why the earth moves in a regular path. As the earth is traveling around the sun, there is a force that is pulling it out away from the sun. There is also a force that pulls the earth toward the sun, like the rubber band on the ball. The earth stays in a path where these forces are equal. This is at a distance of about 93 million miles from the sun. Round and round the earth goes, held in its path by these two forces. We call this path around the sun an *orbit.* The earth's orbit is nearly a circle.

The earth is only one of nine planets traveling around the sun. Two of these planets are closer to the sun than the earth is, and six are farther away. Each planet travels in its own orbit. Since each of the planets is held in its own path, there is no possibility of their running into each other. The nine planets all move around the sun in the same direction.

Do you know how large this solar system is? It is about seven billion miles across. We might think of the solar system as a huge victrola record with a ball (the sun) at the center. Then there would be nine little balls (the planets), each rolling in its own circle on the record around and around the sun.

But the sun and the planets are not the only bodies in the solar system. There are one or more moons circling around most of the planets. Each of the moons goes in its own path around its planet and is held in its orbit by the same forces that hold the planets in theirs. There are also comets in the solar system. You will learn about these later in the unit.

You must remember that the planets are not



Because one side of Pluto's orbit is nearer the sun than the other, it may seem that Pluto travels part of the time in Neptune's orbit. But it travels higher than Neptune and so has a separate path. To see how large the sun and the planets are in comparison with each other, study the picture on page 289.

stars. Stars are immense balls of extremely hot glowing gases like our sun. They shine with their own light because they are so hot. The planets are small bodies when compared with the sun or the stars. Planets are dark and cold except when they are lighted and heated by the sun. A planet can be seen in just the same way that a house can be seen. Light from the sun strikes the house or the planet, and it reflects this light.

Of course, you remember that the earth spins on its axis. Every 24 hours the earth turns completely around on its axis, and we have daylight and darkness. Each planet also turns on its axis as it goes on its journey around the sun.

The turning of the earth on its axis is steadier than any motion we can make by a machine. Man has not been able to make any clock keep time so well, year in and year out, as the earth spinning on its axis. It never changes from year to year. All the planets move just as regularly as the earth does. Planets move so regularly in their orbits that scientists today know exactly where a planet is at any time. They can turn their telescopes to that spot in the sky and find the planet there. The solar system is like a gigantic machine that keeps moving in the same orderly way and never stops.

People have sometimes been afraid that the earth would bump into another planet and be destroyed. Of course, you know that this could not happen. All planets have their regular paths, and each is held in its own path by the same forces that hold the earth in its orbit. There is no reason for believing that they will ever run into each other.

* * *

1. What body is at the center of the solar system?
2. Why can we see the planets?
3. How do planets move?
4. What is an orbit?
5. In what three ways are all planets alike?

What have astronomers found out about the different planets?

AN ASTRONOMER is a scientist who studies all the bodies in the universe, such as the sun, moon, stars, and planets. He tries to find how large these bodies are, what they are made of, how they move, and how fast they move. Some facts that they know about the planets are shown in this table.

Names of Planets	Size (Approximate Diameter in Miles)	Distance from the Sun in Miles	Time It Takes to Travel around the Sun	Speed (Miles per Second)	Number of Moons
		Millions	Days		
Mercury	3,000	36	88	29.7	0
Venus	7,700	67	225	21.7	0
Earth	8,000	93	$365\frac{1}{4}$	18.5	1
Mars	4,300	142	687	15.	2
			Years		
Jupiter	88,400	483	11.8	8.	11
Saturn	74,150	886	29.5	6.	9 (3 rings)
Uranus	30,200	1,782	84.	4.2	4
Neptune	34,800	2,793	164.5	3.4	1
Pluto	?	4,000?	247.7	2.9	?

At the top of each column in this table are several words that tell you the kind of information found in the column. At the left is the name of each planet. If you want to find the size of Mercury, for example, you look on the same line as Mercury in the column marked "Size." How large do you find this planet

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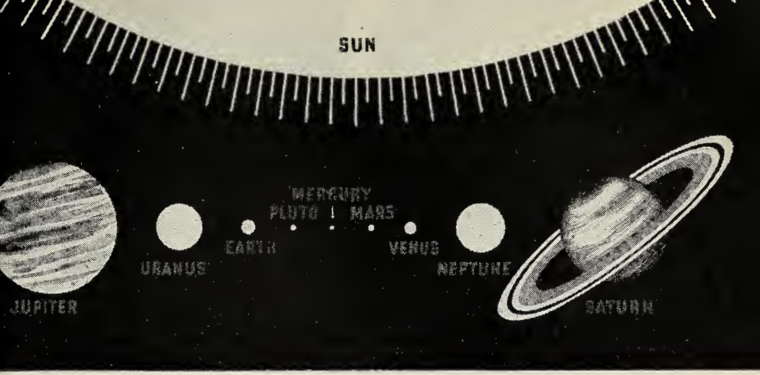
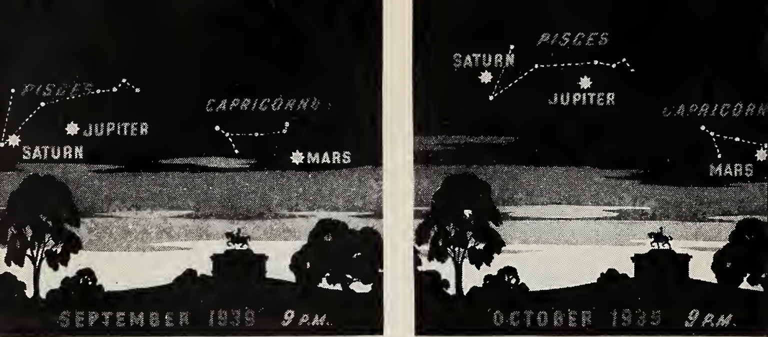


How small the earth seems compared with the giant planet, Jupiter! And even Jupiter seems small when you compare the planets with the sun.

to be? Is it larger or smaller than the earth? How can you tell? From this table you can see that there is one other planet about the same size as the earth and that there are two smaller planets. What are their names? What four planets are much larger than the earth?

To find the distance of Venus from the sun, you would find the number on the same line with Venus, but in the column marked "Distance from the Sun." Do you find that Venus is 67 million miles from the sun? Which one of the planets is nearest the sun? Which is the farthest away? Neptune is how many times as far from the sun as the earth is? Neptune is about thirty times as far from the sun as we are.

Now study the table to find how long it takes the different planets to travel around the sun. How



Notice how much Mars, Jupiter, and Saturn have moved in one month. People long ago saw these bodies move among the stars. They called them "planets" from a word meaning wanderer. Because the planets are moving around the sun, we see them in different places in the sky.

many days does it take Mercury to go around its orbit? How many times can Mercury travel around the sun while we are going around once? It takes Pluto almost 250 years to make one trip around the sun. Mercury, though, goes at a much faster speed than Pluto. What is the speed of Mercury?

If you look in the column headed "Number of Moons," you will find that Mercury and Venus have no moons, while Jupiter has eleven moons.

In the line describing Pluto you will find a number of question marks. Scientists do not yet know the exact size of Pluto or just how far it is from the sun.

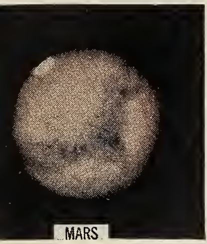
Do the names of the planets interest you? The planets were named for the gods and goddesses of the old Roman myths. In these legends Mercury was the swift messenger of the gods. It was therefore very fitting that the swiftest-moving planet should be called Mercury. This planet travels at the great speed of nearly thirty miles a second! In less than three months Mercury completes its journey around the sun.

Mercury is not easy to see because it stays so close to the sun. Sometimes, though, in the early evening just after the sun has set, you can see Mercury in the western sky. Most astronomers believe that there is no air or water on Mercury. If that is true, could there be any living things on the planet?

Venus is the brightest of all planets. In fact, Venus is brighter than any other heavenly body except the sun and the moon. It was called Venus because it is so beautiful, for in the old myths Venus was the goddess of beauty. You often see Venus as the "Evening Star." You know, though, that Venus is not a star at all. It is a planet that is about the same size as the earth. The earth and Venus are often called "sister planets."

If you could look at Venus through a telescope, you would see it surrounded by clouds. Although Venus comes nearer to the earth than any other planet, its surface cannot be seen clearly because of these clouds. Perhaps Venus may have life on it. We do not know.

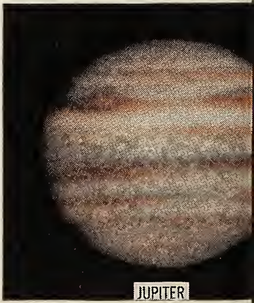
Mars got its name because of its reddish color. Mars was the Roman god of war, and the red planet


MARS

Mars represented war and bloodshed. We know more about Mars than any other planet. A day on Mars is about the same length as our day. There are seasons on that planet, just as on the earth. The seasons are longer than ours, for on Mars a year is nearly twice as long as a year on the earth. Because Mars is farther from the sun than the earth is, it is colder.

Water is scarce on Mars. There seem to be no oceans and no seas on it. Much of Mars is probably dry desert. The air there is very thin and somewhat like the air on a high mountain on the earth. Since there are both air and water on Mars, this planet could have life on it.

Through a telescope Mars looks like a reddish-colored ball with interesting markings on it. These markings have puzzled the astronomers. In the spring of the year on Mars some of these markings are a bluish green, but in the autumn they turn brown. If green plants were growing there, they would probably be green in the spring and brown in autumn, just as the plants are on the earth. The latest photographs of Mars seem to show that there may really be plant life on it.


JUPITER

Jupiter, the giant planet, was named for Jupiter, the king of the Roman gods. Jupiter is larger than all of the other planets would be if they were rolled together. It turns completely around on its axis in about ten hours. This means that Jupiter spins around at great speed, for it is very much larger than the earth. Jupiter is almost as bright as Venus and is usually much brighter than any of the stars.

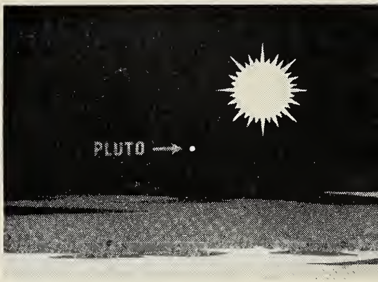
If you look at Jupiter through a telescope, you see that it, like Venus, is surrounded by dense clouds. These clouds look like belts around the planet. Jupiter has eleven moons. You can see four with a pair of good field-glasses. Galileo, with his telescope, was the first scientist to see Jupiter's moons. Two of Jupiter's moons were just recently discovered. This shows how scientific information is growing, as astronomers find out more about the universe.

If you ever have a chance to look at Saturn through a telescope, you will see a sight that you will never forget. You will probably say that Saturn is the most beautiful of all the planets. It is different from the other planets because it has three huge rings circling it. These rings are made of millions of small particles, or tiny moons, moving around Saturn in a very thin sheet. There is a dark ring close to the planet, and there are two bright rings separated by a space between them. Galileo, with his telescope, was the first to discover Saturn's rings. Saturn also has nine moons that travel around it. These moons are farther from the planet than the rings are.

Still farther away from the sun is the planet Uranus. It is so far away that we can hardly see it with the naked eye. The earth makes 84 trips around the sun while Uranus is making one. Uranus turns on its axis so slowly that it takes about eleven years to turn once. Uranus was accidentally discovered in 1781 by Sir William Herschel as he was trying out a new telescope that he had just made.

Neptune is so very far away that it cannot be seen with the naked eye. In the old Roman legends Neptune was god of the sea. He was also the brother of Jupiter. The story of the discovery of Neptune is a very interesting one. Uranus was not following exactly the path that astronomers thought it should. Some thought that there was a heavenly body out beyond Uranus that was pulling it off the track. Several astronomers spent months working out the problem of finding where such a body would be. One of these men wrote to the observatory at Berlin, Germany, telling just where he figured the planet ought to be. And sure enough, when the telescope was turned to that place in the sky, there it was!

In 1930 another planet was discovered. It was named Pluto. Pluto is about forty times as far from the sun as the earth. It can be seen only with a powerful telescope, and we do not yet know much about the planet. Some astronomers think that beyond Pluto there are other planets circling the sun. Perhaps you may some day read of their discovery.



Pluto looks very small, even through a powerful telescope. Near it in the picture is a star the size of the smallest star in the Big Dipper's bowl.

If you look at the picture of the solar system on page 286, you will find a great many small bodies shown between the orbits of Mars and Jupiter. These are called *planetoids*, which means little planets. There are many of these tiny bodies swinging around the sun. More than a thousand of them are known by astronomers today, and probably many more will be discovered. Most of the planetoids are less than 50 miles across.

The newspapers often tell what planets can be seen each night, and you will enjoy looking for them. After you have seen the different planets several times, it will be easy to recognize them.

Have you ever heard radio programs or read stories or cartoons telling of people from the earth visiting other planets in rocket ships? Or have you read stories about people from other planets landing on the earth? Some of these stories tell about creatures from Mars coming to the earth to destroy us. Of course you know that these are not true stories; so there is no need to become frightened by them. You can enjoy these stories just as you do any other fanciful tale.

You will enjoy stories about imaginary people from Mars or other planets if you try this plan. After you have heard or read the story, make a list of all the things that you have just learned which show you that the story could not be a true one.

1. Which planet do we know most about? Why?
2. How many planets have been discovered?
3. Select one planet and tell all you know about it.
4. Which planet comes closest to the earth?
5. How was Neptune found?

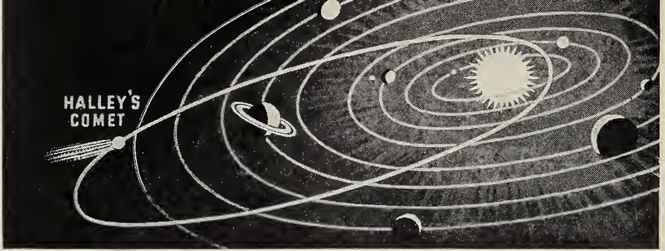
What are comets?

People who lived hundreds of years ago were accustomed to seeing planets, stars, and the moon. But every once in awhile they were frightened by something in the sky which came nearer and nearer and got brighter and brighter. They thought that this strange, bright object might keep coming until it hit the earth! It did not look like the other bodies in the sky. It appeared to have a long tail, or streak of light, behind it. We know now that such a bright streamer of light is a *comet.*

Unlike a "shooting star," a comet can be seen for many nights. A "shooting star" can be seen for only a few seconds.

A comet is different from any of the planets. Planets, you remember, are big round balls, but a comet usually has a head and a tail. The head may be 50,000 miles across, and the tail is sometimes 100 million miles long.

A comet is made of gases and little solid particles. These are clustered together in the head but are very, very far apart in the tail. Perhaps you can better understand this when you know that 2000 cubic miles of the tail of a great comet, known as Halley's comet, would not contain as much material as one cubic inch of ordinary air on the earth. This shows that there is no reason for us to be afraid if the earth passes through the tail of a comet. In fact, this has happened several times. In May, 1910, we passed through part of the tail of Halley's comet.



You can see why a comet can come near a planet. The orbit of a comet crosses the orbits of the planets.

Comets travel around the sun, but their orbits are very different from those of the planets. A planet, you remember, moves around in a path that is nearly a circle, with the sun in the center of it. A comet's orbit is a long, long oval with the sun very near one end of the orbit. Curiously enough, the tail of a comet always points away from the sun.

It is only when a comet comes near to both the sun and the earth that we can see it. Astronomers can figure the length of a comet's orbit and how fast the comet is traveling. They can therefore tell when a comet is coming close enough for us to see it. Some comets race around their orbits in a few years. Others have such long orbits that they can be seen only once in hundreds of years. We can see comets because they, like planets, reflect the light from the sun. A large comet is a beautiful sight.

Halley's comet is the most famous of all comets. It was named for Edmund Halley, an English astronomer, because it was he who first figured out the path that the comet takes. Halley wrote, "Now, many things lead me to believe that the comet of the year 1531 is the same as that seen in 1607 and the one I saw return in 1682. I may, therefore, with confidence predict its return in the year 1758." And the comet came on Christmas night, 1758. This proved that comets are members of the solar system. It also showed that Halley's comet returns to a place in its orbit where it can be seen from the earth every seventy-six years. It last appeared in the year 1910. No doubt many of your class will see it when it comes again in 1986.

1. How is a comet different from a planet?
2. Why can a comet be seen only occasionally?
3. How does the tail of a comet point?
4. What is the name of the most famous comet?

What causes an eclipse?

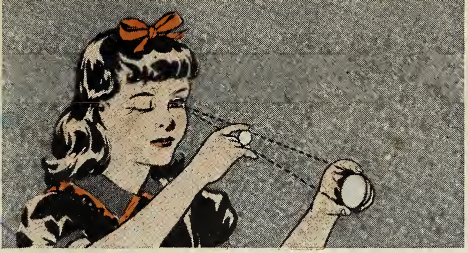
As the earth spins along in its path around the sun, the moon travels around the earth. The earth spins on its axis 365¼ times as it makes its trip around the sun. And while the earth is on its journey, the moon travels completely around the earth every 29½ days. The moon keeps the same half always turned toward the earth.

You can get a better idea of just how the earth and the moon move if you use three balls to show this. Have a girl hold a large ball to represent the

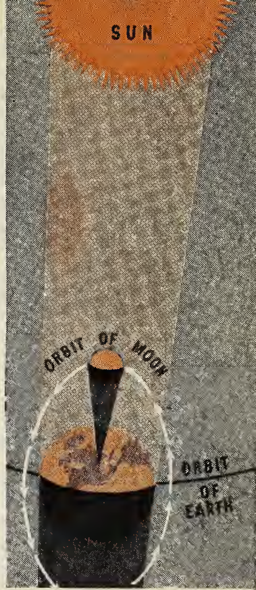
sun, have another girl carry a globe to represent the earth, and have a boy carry a small ball to represent the moon. Each must think just how his ball is to move. The girl carrying the globe must walk in a large circle around the sun and must constantly keep turning the globe on its axis. She must not go too fast, because the boy with the small ball representing the moon must keep running around her.

After watching the way the three balls are moving, perhaps you can now realize how the earth and the moon are moving through space around the sun.

Once a month, as the moon circles around the earth, it comes between the sun and the earth. Most of the time, though, it does not pass directly between the sun and earth. But every so often the moon passes exactly between the sun and the earth. Then a most interesting thing occurs. The moon hides the sun from view, and we have an *eclipse* of the sun. The word *eclipse* means to cover up.



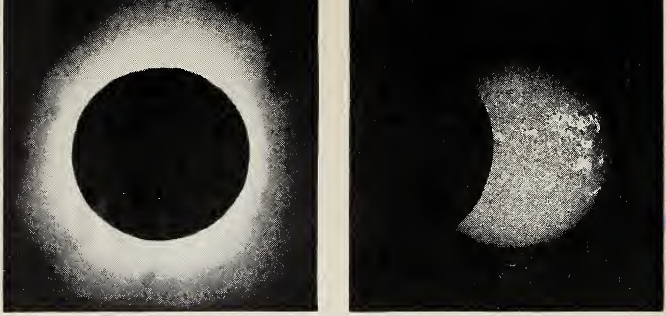
The picture at the right shows what happens when there is an eclipse of the sun. The people living at the place where the shadow of the moon strikes the earth cannot see the sun.



You are probably wondering how the moon can entirely hide the sun, because the moon is so very much smaller than the sun. This experiment will help you discover the reason. Take a one-cent piece in one hand and a half-dollar in the other. Close one eye and hold the coins in front of your open eye so that the cent is near and the half-dollar is farther away.

Move the half-dollar back until the cent hides the half-dollar. Is the cent as large as the half-dollar? Which is nearer? This shows that the nearer things are, the larger they look. That is why the moon and the sun look to be about the same size in the sky. Do you now see the reason why the small moon, which is near, can hide the big sun, which is far away?

In an eclipse of the sun, the moon is between the sun and the earth. Therefore the moon keeps the light of the sun from reaching part of the earth. So,



At the left you can see a misty light around the sun in a total eclipse. At the right the moon covers only part of the sun, causing a partial eclipse.

as the moon slowly hides more and more of the sun from the earth, the earth gets darker and darker.

When the moon passes directly in front of the sun, the eclipse is called a *total eclipse.* A total eclipse of the sun is one of the most interesting sights that it is possible to see. Just when the sun is totally hidden by the moon is an exciting moment. A great mist of silvery white light surrounds the sun. This silvery light is a layer of thin gas that surrounds the sun at all times. It is only during a total eclipse of the sun that it can be seen. When the moon only partly covers the sun, the eclipse is called a *partial eclipse.*

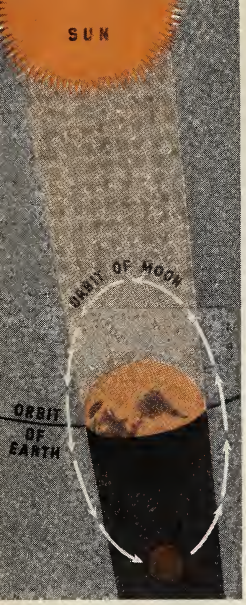
You are probably wondering why there is not an eclipse of the sun every time the moon passes between the earth and the sun. You can see that the moon must be directly between the earth and the sun to cause an eclipse if you try this experiment with the cent and the half-dollar. Hold them as you did before; then move the cent until it is a little above or a little below the line from your eye to the half-dollar. The cent then will not cover any of the half-dollar. So, if the moon is not directly between the earth and the sun, there is no eclipse.

In the few minutes during a total eclipse, astronomers can learn many things about the sun. They often go great distances to the place on the earth where they can best see the eclipse. Months are spent making plans and getting equipment so that everything may be ready for the precious few minutes when the sun is covered. One way in which scientists study an eclipse is to take photographs of it.

You, too, will want to watch an eclipse of the sun. To do this, you can look through a piece of smoked glass or several exposed kodak films. You must never look at the sun even for one second without using the smoked glass or kodak films, for of course you do not want to injure your eyes. As you watch the eclipse, you can make drawings showing just how the moon is moving across the sun.

Today astronomers can tell exactly when an eclipse is going to happen. They can do this because they know the exact paths over which the earth and the moon travel and the speed at which they travel.

There will be a total eclipse of the sun on July 9, 1945. It will be seen in Idaho and Montana and in central Canada. An eclipse on June 30, 1954, will be seen in Canada and in Minnesota and Wisconsin.



As the shadow of the earth covers more and more of the moon, the moon looks like the photographs above. But even in a total eclipse sometimes enough light strikes the moon to make it look dull red.

Did you ever watch an eclipse of the moon? Do you know what happens to cause this eclipse? As the moon is continually traveling around the earth, occasionally the earth is directly between the sun and the moon. The sun of course cannot shine through the earth, and therefore the earth makes a shadow. Can you imagine what a long shadow the big earth makes? The earth's shadow is long enough to reach the moon. When the earth is directly between the sun and the moon, the earth's shadow falls on the moon. We can see this shadow on the moon. As the shadow covers up, or hides, part of the moon, there is an eclipse of the moon.

Have you heard the story of how Columbus got food from the Indians by knowing that an eclipse of the moon was to occur on March 1, 1504? He told the Indians that if they did not give his men food, he would make the moon disappear. When the

Indians saw the moon being darkened by the shadow of the earth, they were afraid and gave Columbus anything he wanted.

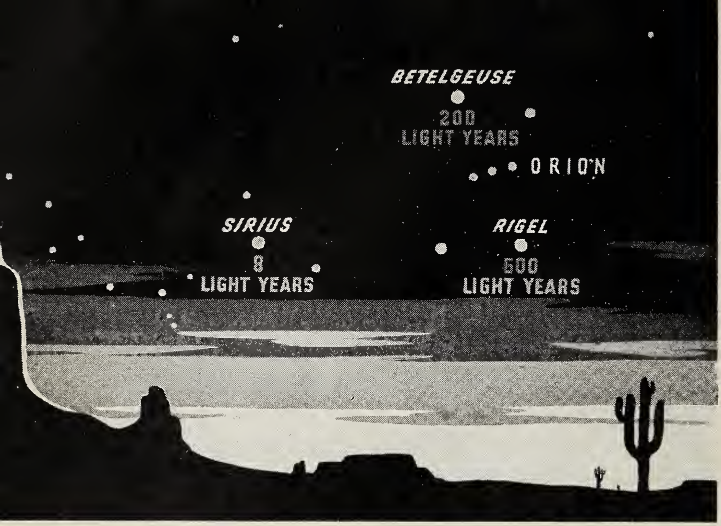
* * *

1. What happens when there is a total eclipse of the sun?
2. What part of the sun can we see only during a total eclipse of the sun?
3. Why do the small moon and the big sun appear to be about the same size in the sky?
4. During an eclipse of the moon, what shadow do you see on the moon?

What is beyond the solar system?

It is hard for us to imagine the distances in the solar system. The planets are so far from the sun that we speak of these distances in millions of miles. Can you think how far a million miles is? The distance around the earth is twenty-five thousand miles. How many times would you need to go around the earth to travel one million miles? Forty times. Then think that the sun is ninety-three million miles away!

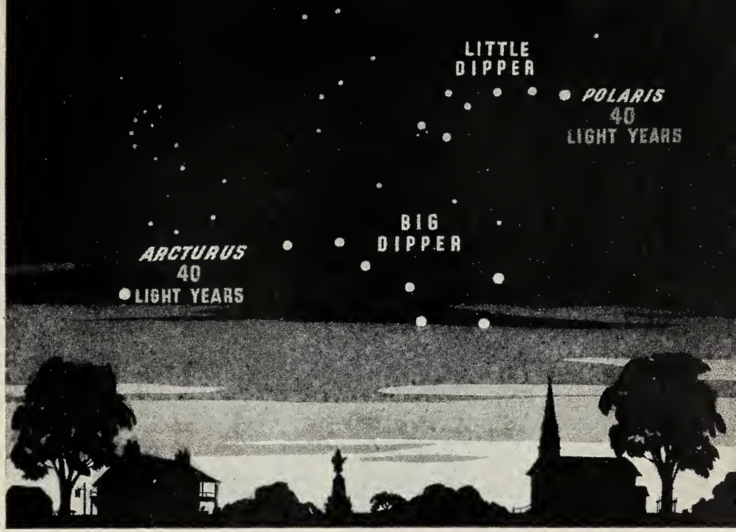
But far, far beyond the solar system are the stars. The nearest star is nearly thirty million million miles from the earth. The stars are so far away that scientists do not use miles to tell their distances. A mile



When you look at the stars, remember that you are looking off into space. Betelgeuse, Rigel, and Sirius may seem to be about the same distance away. But Rigel is three times farther off than Betelgeuse, and they are both many times farther off than Sirius.

is too short a measure. It would be like telling the distance from New York to San Francisco in inches. Astronomers therefore use what is called a *light year* to measure the distances of the stars. Light, as you already know, travels 186,000 miles a second. A light year is the distance that light travels in one year. One light year is nearly six trillion miles. To write this number, you need to place twelve zeros after the six. This is indeed a big number. A light year is used as the "measuring stick" of the universe.

Now let us find out how far away some of the



Polaris and Arcturus are much nearer than Betelgeuse and Rigel. Are they brighter? Find out by looking for them tonight.

stars are. Sirius is the brightest star in the sky. You can easily locate Sirius because it is near the constellation Orion. Sirius is a little more than eight light years, or we can say that it is more than 48 trillion miles from the earth. And Sirius is one of the nearest stars. Do you know where the star Arcturus is? Find the Big Dipper in the northern sky. Then follow the curved handle in the Big Dipper to twice its length. There you see the bright star Arcturus. Arcturus is forty light years away. It, too, is one of the nearer stars.

Another star that is forty light years away is Polaris, the North Star. Betelgeuse, the giant red

Telescopes such as this big one in Yerkes Observatory help astronomers study the stars. Most of the photographs in this unit were taken through telescopes.

star in the constellation of Orion, is two hundred light years away. Rigel, the brilliant bluish white star in Orion, is about six hundred light years from the earth. The distances of many of the stars are thousands of light years. When you think that light takes only *eight minutes* to travel from the sun to the earth, you can realize how far distant the stars are.

The stars in a constellation look close together, but they may be many light years apart. And there are many stars that are too far away for us to see with the naked eye. When an astronomer takes a photograph of just a small part of the universe, it shows millions of stars. We know, then, that there are billions of stars in the universe.

And some of these stars are many, many times as large as our sun. Betelgeuse, one of the largest, is a real giant among the stars. Betelgeuse would make about thirty million suns the size of our own. Some of the stars may have planets traveling around them just as our sun has. We do not know whether there are other solar systems or not, but it seems very probable that there are.

You can see from what you have learned that the earth on which we live is only a small speck in a big universe. It appears large to us, but in a universe where distances are measured in trillions of miles, the earth is just a dwarf among giants. It is only one of thousands of millions of heavenly bodies. And we are only tiny dots on a small earth.

1. What is a light year?

2. Why do astronomers use a light year to measure distances to the stars?

3. How far from the earth are some of the nearest stars?

Questions to Answer

1. Describe the universe. Be sure that you include everything you have learned.

2. Which of these bodies are in the solar system: the earth, stars, Jupiter, Polaris, the sun, Mars, planets, Rigel, comets, Pluto, the moon, Saturn, planetoids?

3. What is the difference between a planet's orbit and a comet's orbit?

4. Why would you not be frightened if you were told that a comet was coming nearer and nearer the earth?

5. If you were an astronomer, what one thing that is not known today would you like to discover?

6. Which of the following sentences about planets are true?

a) They each travel around the sun in a definite orbit.
b) They can be seen because they reflect light.
c) They are larger than the stars.
d) They are all traveling in the same direction around the sun.
e) They are all the same size and the same distance from the sun.
f) They get their light and heat from the sun.
g) Each of the planets turns around on an axis.

7. Put the following in order according to their distance from the earth. Refer to your book while you are doing this. Begin with the nearest one: the sun, Venus, Sirius, the moon, Betelgeuse, Arcturus, Rigel.

8. Do you think that some kinds of plants and animals live on Mars? Give reasons for your answer.

9. Tell why you know whether this is from a true story or from an imaginary one: "The giants from Mars made a quiet landing on the earth. Quickly they climbed out of their rocket ship and looked around at this strange world."

Things to Find Out

1. Find out when there will be an eclipse of the moon and then watch this eclipse. You might make drawings of the earth's shadow as it passes across the moon.

2. In July, 1939, Mars was only 36 million miles from the earth. Sometimes it is 230 million miles away. Find out why this is true. Make a drawing that shows the position of Mars and the

earth in their orbits when they are near each other, and when they are far apart.

3. Find out what a planetarium is and what cities in our country have a planetarium. If you visit one of these cities, you will want to go to the planetarium.

4. Find out when one of the planets can be seen. Then try to locate this planet and look at it every few weeks. Each time make a drawing showing the position of the planet and the stars near it. Be sure to put the date on each drawing. Then examine your drawings to see if they show that the planet is moving.

5. Suppose you were making a model of the solar system and using 1 inch to stand for 1 million miles. Find how many inches from the sun you would place each of the balls representing the planets. Could you make this model in your school-room or school-yard?

6. Find out where some of the large observatories in the United States are located. If you live near one of these, you will want to visit it to see the telescope.

7. Find out when the next bright comet can be seen.

8. Find out when there will be an eclipse of the sun. How can you get ready to watch this?

Pages 320 and 321 will tell you what this picture shows.

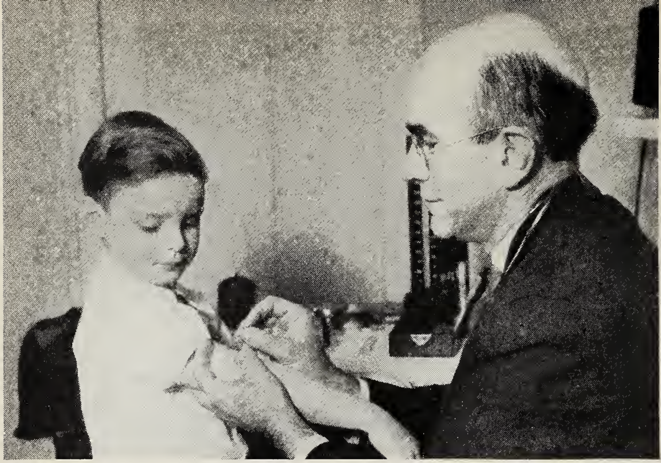
UNIT EIGHT

HOW CAN WE KEEP WELL?

IN THE MIDDLE of a winter not many years ago a terrible *epidemic* of diphtheria broke out in the city of Nome, Alaska. Hundreds of people were ill, and many were dying. One thing, and only one thing, could save the people. That one thing was diphtheria *serum*, which scientists had learned how to make. This serum would keep the well people from becoming ill, and it would cure many of the sick people. But there was no serum in Nome. The nearest serum was in Fairbanks, hundreds of miles away, and there were no trains or airplanes.

It was then that a brave man and some brave dogs came forward to save the people of Nome. Perhaps you have read how Gunnar Kasson with his dog team headed by the famous dog Balto struggled across ice and snow through blizzards to carry the serum to Nome. In New York City there is a statue to Balto and his master.

This story should raise some questions in your mind. How does diphtheria make you ill? How does a serum cure people? Before you begin your study of this unit, suppose you talk over in class what you



This boy is being *vaccinated* to help him keep from getting sick. Millions of boys and girls and men and women have been saved from illness by vaccination. In this unit you will learn how vaccination helps your body fight disease.

already know about diseases. Perhaps some of you know what an epidemic is. Find out how much you already know, and then make a list of questions about diseases that you would like to have answered. While you are studying the unit, talk to your family doctor, your school nurse, and your father and mother. Ask them to help you learn more about how you can keep your body well.

What are bacteria?

YOU HAVE HEARD many times that some diseases are caused by *bacteria*. Before we study how bacteria cause disease, let us find out some of the things that scientists have learned about bacteria,

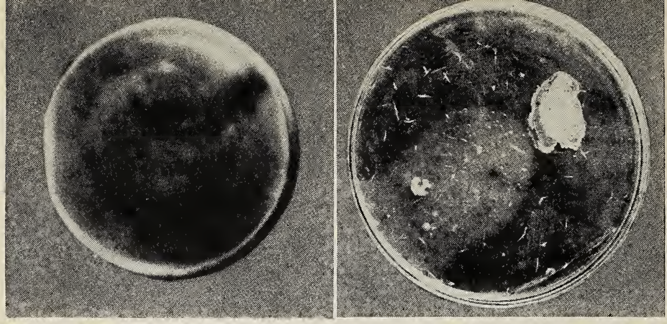
These are Petri dishes like the ones you will use to grow bacteria gardens.

which are the smallest of all plants. First, we will try to grow some bacteria. You can plant and grow bacteria if you will follow these directions carefully.

Get six dishes like those in the picture. They are called Petri dishes. Bake your dishes in a hot oven for about two hours. This is to be sure that they do not have live bacteria on them. When you take them from the oven, be careful not to raise the covers. Next, get some food ready for the bacteria that you will grow. Your teacher will tell you how to make it or where to get it.

Fill six test-tubes half full of the liquid food and plug the tubes with wads of cotton. Be sure that the cotton wad is tight. Set the test-tubes in a container with three or four inches of water. Boil slowly for about forty-five minutes. Now all the bacteria have been killed in the food.

Place the six Petri dishes on a table and carefully follow these directions in filling them. If the food has hardened in the test-tubes, heat the tubes again in

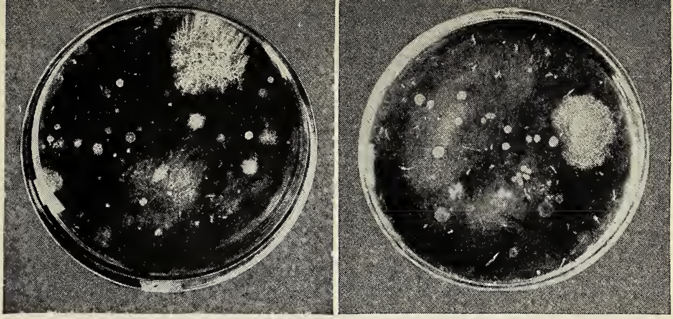


The food in the Petri dish at the left was kept clean. No bacteria grew in it. The bacteria in the right-hand dish came from a few drops of dirty water spread over the food.

water. Remove the wad of cotton from a test-tube, lift the cover of a dish, and pour the food into the dish, covering the dish again quickly. Empty one test-tube into each dish in this way. The food will soon harden, and your gardens will be ready to plant.

Now to plant your gardens! It will not be hard to find some bacteria, but you should be careful to follow these directions for planting. Plant garden Number One by lifting the glass a little way and touching a pencil to the food material. Attach a label to this garden so that you can remember how you planted it. Cover the garden at once and seal it with gummed paper. Each garden should be sealed and labeled in the same way after it is planted.

Plant garden Number Two by putting a few drops of milk on the food. After the Petri dish has been covered, tip it from one side to another to be sure the milk is fairly well spread over the surface. Garden Number Three you may plant by letting someone

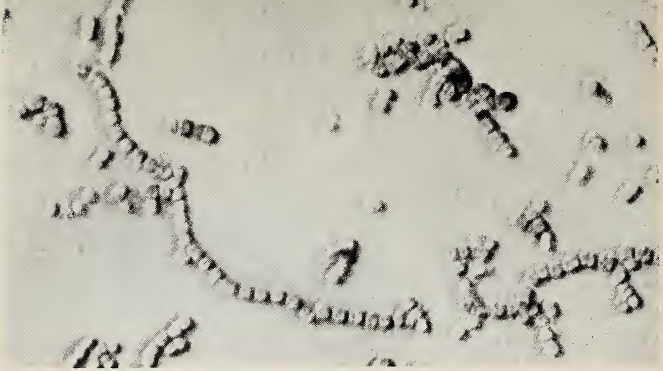


The cover was left off the dish at the left for twenty minutes. Bacteria from the air dropped on the food and began to grow. Somebody touched his fingers to the food in the dish at the right and planted a good garden of bacteria.

touch the food with his fingers. Garden Number Four may be left open for a few moments so that the air can touch the food. Plant garden Number Five by touching the food with the flat surface of a penny or other coin. If a fly should happen to walk across this garden, you would have a still better planting of bacteria.

Garden Number Six should be sealed and kept sealed. Do not plant any bacteria in it. Do you know why? It is left so that you may be sure there are no bacteria in the food. If no bacteria grow in this garden, then you will know that the bacteria in the other gardens really come from the pencil, the milk, the fingers, the air, and the coin.

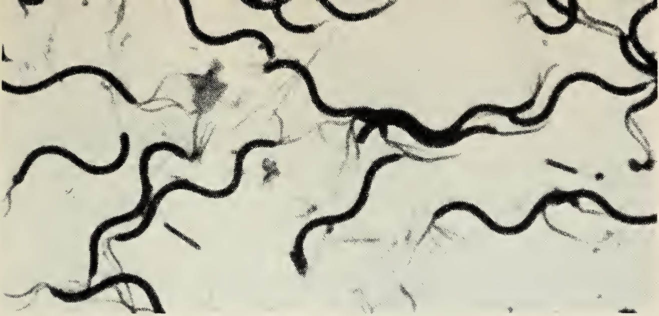
Place these gardens in a warm, dark place for a few days and then examine them. Do not examine them until at least forty-eight hours after you have put them away. Then you will probably find that



Here are some ball-shaped bacteria. These usually hang together in strings; those on page 323 are in bunches. Sometimes each bacterium stays separate from the others. This picture was taken through a microscope that magnified the bacteria 2500 times.

your gardens look like the pictures on page 316 and page 317. The fuzzy places are molds. The yellow or white spots in your gardens show where the bacteria are growing.

If you could look at bacteria through a microscope, you would find that they have different shapes. Some are tiny round balls, like the ones on this page and on page 323, while some are spiral like a corkscrew, and others are rod-shaped. But bacteria are all alike in one way. Each of these bacteria is just one cell. Probably you can remember reading that cells are tiny blocks of living material. Your own body is made of billions of cells. But each of these bacteria is made of only one cell. Some of them are so small that it would take thousands of them to cover the period at the end of this sentence.



These bacteria are spiral in shape. They were magnified 1500 times to take this picture.

Bacteria have a very simple way of making more of their own kind. They multiply by dividing! Each tiny one-celled plant divides and makes two separate smaller plants. These grow to their full size, and then each divides. This happens very quickly. One plant may grow and split into two parts in half an hour or less. Suppose you figure how many bacteria there would be in 12 hours if each plant grew and divided. The table below will show you how to start.

TIME	NUMBER OF PLANTS
½ hour	2 bacteria
1 “	4 “
1½ “	8 “
2 “	16 “
2½ “	32 “

You can see there would be millions in twenty-four hours. Millions of these one-celled plants are growing in the gardens. Of course you should not touch these bacteria with your fingers.

The dishes in which bacteria are growing have a very unpleasant odor. The bacteria are changing the characteristics of the food; so we know that they are causing a chemical change. Bacteria cause dead plants and animals to decay. These decayed materials go back into the soil where they may be used by other plants. If it were not for bacteria, we would probably be climbing over huge piles of dinosaurs or dead trees!

But some kinds of bacteria are very dangerous. They cause disease, and are man's greatest enemies. Other bacteria are man's greatest friends.

1. Why did you bake the Petri dishes?
2. Why was it necessary to plug the test-tubes with cotton and heat them?
3. Why was one garden not planted?
4. How many cells are there in each bacterium?
5. How do bacteria make more bacteria?
6. Name an important thing that bacteria do for us.

How have scientists found out about bacteria?

But how did we find out about these smallest of plants? About 250 years ago a man named Anton van Leeuwenhoek, who lived in Holland, invented the microscope. By putting two lenses together he found that they made things appear much larger.

With this he could see many things that could not be seen at all with the naked eye. He was interested in looking at many things with his microscope, such as a fly's head and a bee's stinger. One day he put a drop of water under his microscope. When he looked, he called to his daughter, "See these thousands of little animals!" He was the first to see these tiny things. And years later, scientists found that some of these were bacteria.

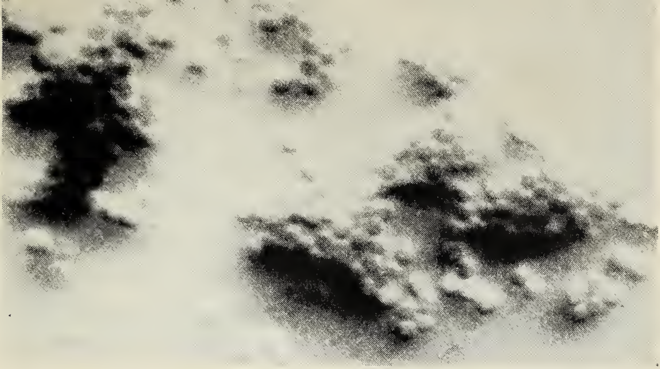
But for years after Leeuwenhoek saw bacteria, no one ever dreamed that such things could make people sick. It was just about 75 years ago that scientists were able to prove that some diseases are caused by bacteria.

The scientific discoveries of Louis Pasteur have helped millions of people all over the world.

Two scientists will always be remembered for their great work in discovering that bacteria cause some diseases and in inventing methods for preventing and curing these diseases. One of them, Louis Pasteur, a great French scientist, knew that tiny plants called yeasts caused wines and beers to ferment. He tried to find out why some of these liquids spoiled. When he examined them under a microscope, he found other living objects even smaller than the tiny yeast plants. He also looked at lumps of sour milk and saw similar tiny living things. Pasteur began to wonder if some diseases in the human body might also be caused by these tiny things. We now know that these tiny things that Pasteur saw were bacteria.

Fortunately, just about that time, Pasteur was asked to help with the problem of a disease that had already killed many silkworms. In southern France the chief industry then was the raising of silkworms. So it was a serious situation when thousands of these insects were dying. It was easy to tell when the caterpillars had the disease, for they had little dark spots on them. Pasteur studied these under a microscope and found bacteria there, too. He fed some of these bacteria to healthy silkworms, and they got the disease! He knew then that the only way to conquer the disease was to get rid of the bacteria. He did this by killing all the diseased caterpillars and destroying their eggs.

Pasteur's work saved the people of France millions of dollars by saving their silk industry. But even more important was the fact that Pasteur had proved that tiny bacteria caused disease in an animal. Finally, a German scientist, Dr. Robert Koch, was able to



Bacteria of this kind are usually found on the skin. When the skin is cut or broken, they may cause a sore. To get this picture, the germs were magnified 2000 times.

prove that some diseases in our bodies are also caused by bacteria. The world owes a great debt to Louis Pasteur and to Robert Koch. Their discoveries have saved and will save the lives of millions of boys and girls and men and women.

Scientists have also discovered animals that are about as small as bacteria. Some of these animals can cause disease, too. It is hard to believe that such tiny plants and animals can make us sick when they get into our bodies. But we know that this is true because it has been proved. You have probably heard these tiny plants and animals called *germs*. Germ is the name that we use for any of these plants or animals that make people ill.

After the discoveries of Pasteur and Koch, diseases were studied in a new way. Scientists began to experiment to discover which diseases were caused by germs and just what kind of germ caused each one. The experiments had to be done very carefully and repeated over and over before the scientists could be sure that a disease was caused by a certain kind of germ.

Scientists like this man are working every day in laboratories with microscopes and test-tubes to find the causes of disease.

Today scientists are still searching for causes of diseases. They have found that scarlet fever is caused by one kind of germ, tuberculosis by another, typhoid fever by another, and so on through a long list of diseases. Each of these diseases is caused by a certain kind of germ. The search is still going on, because there are many diseases for which no germ has been found. You have never seen a picture of an influenza germ, for instance, nor a cold germ, nor a smallpox germ. Scientists believe that germs, or something very much like them, cause these diseases. They act like germ diseases, but no one has ever seen what causes them, even with powerful microscopes.

You must not get the idea, however, that every sickness is caused by germs. Heart disease, for example, is caused by failure of the heart muscles to work as they should. You may have stomach ache when you eat too many green apples or too much chocolate pie. You may have a headache because you have strained your eyes or stayed too long in a room with bad air. Babies have rickets if they are not given the kinds of food that have plenty of bone-building materials in them.

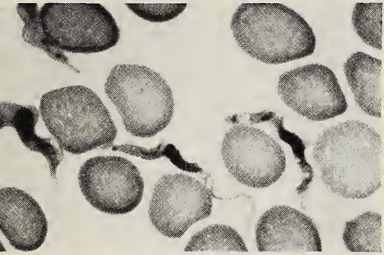
1. What are germs?
2. Tell why these statements are not true.
   - *a*) All germs are bacteria.
   - *b*) All bacteria cause disease.
   - *c*) All diseases are caused by germs.
3. Tell how Pasteur happened to discover disease germs.

How do we "catch" germs?

"If there are any more cases of influenza, we shall close the schools for a week or so," said Dr. Brown, as he finished examining the children in Miss Crane's room. "Tell the girls and boys to be careful to follow the rules I suggested."

"All three of the children in the Smith family are out of school today," said Miss Crane. "They must have caught influenza from George. He was sick first."

If disease germs enter your body, and if they are allowed to go freely about their business, they can soon change your body from a well machine to a sick one. How do these enemies enter your body? Usually they "hitch-hike" in with something that is going their way. Do you know what some of the things are that give disease germs a ride into your body?

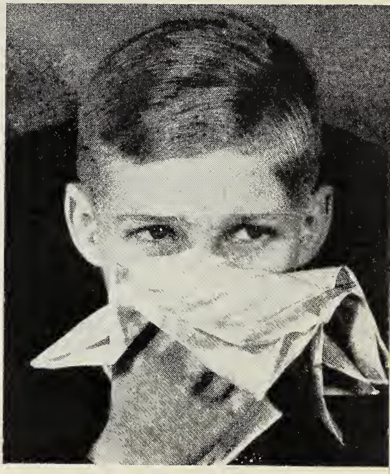


Blood cells and animal disease germs magnified about 1800 times. The four animal germs that you see among the blood cells are the kind that cause one kind of "sleeping sickness."

Some go in with the air you breathe; others with the food you eat. Some flow in with the milk and water you drink. Still others go in through cuts or breaks in your skin. You may even give them a ride in on pencils, on your fingers, or on postage stamps that you touch with your lips and tongue. Your experiments with the bacteria gardens help you to see how bacteria can easily get into your mouth.

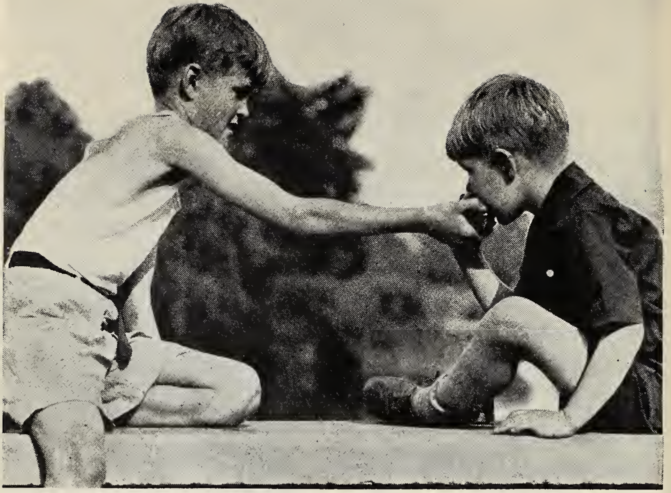
Do you know how germs spread from one person to another in a school-room? Do you know how typhoid fever may get started in a village or city and spread from one person to another? Do you know how you can catch diseases from other persons? Perhaps you are thinking, "Those are easy questions to answer. The germs go from one person to another. Then they begin to grow, and soon they may make you sick."

But germs cannot fly or walk. How, then, do they travel from one place to another? There are several ways. The children in Miss Crane's room spread germs from one to another when they coughed and sneezed. Some of them were not careful to cover their mouths when they coughed; so the germs were sprayed through the air. The spray from a hard cough or sneeze may travel ten or fifteen feet through the air.



Germs escape from a sick person's body through anything that comes from his body. They are in saliva from his mouth, in discharges from his nose, and in anything else that comes from his body. Dishes that a sick person has used and things that he has touched may have germs on them. Handling these things may spread germs. If other people eat from these dishes before the dishes have been properly washed, the disease is often spread.

We often get germs into our bodies when we are not



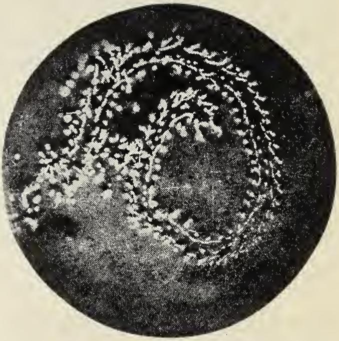
When you give another person a bite from your apple or candy, you may be spreading germs to him or from him to you.

even near a sick person. How does this happen? We may get germs into our bodies by drinking impure water. The germs that cause typhoid fever are often found in water. Before scientists discovered that typhoid germs can live in water, the disease was much more common than it is today.

Almost as many people drink milk as drink water. When cows and cow barns are allowed to become dirty, disease germs often get into the milk that people drink. Then, too, the cows may be sick, or the person who milks them may be sick. If either one of these things is true, of course the milk may have disease germs in it. Cows can become ill from tuberculosis, just as people can. Milk from such cows always has tuberculosis germs in it. One reason why disease germs travel so easily in milk is that milk is excellent food for germs. Other foods, such as vegetables and fruits, may also spread disease germs if they are not kept clean in stores and markets.

Germs often "hitch-hike" from one person to another on insects. Flies are especially likely to carry germs. Flies lay their eggs and get their food in dirty places. They often live in garbage, manure, and trash. Disease germs live in these places, too. Examine a house-fly under a microscope, and you will see thousands of little hairs on its legs.

Germs and dirt stick to these hairs and are carried far and wide. If a fly walked on one of the bacteria gardens you planted, you found bacteria growing where the feet had touched the food. Flies come into your house and alight on the food with their cargo of germs. Then the germs have only a short trip to make with the food into your mouth. Because the house-fly carries typhoid germs, it is sometimes called the typhoid-fly.



A fly walked around on the food in this Petri dish, and all these germs grew from the places where its feet touched.

One kind of mosquito carries malaria, and another kind carries yellow fever. The mosquito picks up disease germs when it bites a sick person and sucks his blood. Then, when this mosquito bites a well person, it thrusts some of the germs into his blood, and he gets sick with the disease. Lice, roaches, and fleas are other insects that can carry disease germs.

Diseases that are caused by germs are called *infectious* diseases. Infectious diseases that can be passed on from one person to another are called *contagious* diseases. We "catch" contagious diseases from the breath of ill people, from touching things that they have touched, and from eating foods that they have handled. Many infectious diseases that are not contagious are carried from one person to another by insects.

1. Name four ways that disease germs can travel from one person to another.
2. Why is it important to kill flies and mosquitoes?
3. What is an infectious disease?
4. What is a contagious disease?

How does the body fight germs?

Can you think of any way that your body keeps germs out? The skin that covers you from head to toe is one very important protection against germs. Of course, when you cut yourself, you make an opening in your skin, and germs can enter through

These Boy Scouts are learning how to put on bandages, a very valuable thing for anyone to know.

this opening. That is why it is so important to keep any cut in your skin very clean. When you put iodine on a cut, it kills germs that may be ready to enter your body.

You remember that germs come into your body with the air you breathe. Some are on the dust that comes in with the air, but hundreds of tiny hairs in your nose help to stop these germs. Many germs are caught by a sticky fluid in the nose. You force these germs out when you use your handkerchief.

But germs are able to get inside you in spite of this protection. You may be wondering where they go after they get inside you. This depends on the kind of germ. Germs go where they can live best. Some kinds can live only in certain parts of the body. For example, pneumonia germs live best in the lungs. Some kinds grow best in the throat and cause a sore throat or sore tonsils. Some kinds grow almost anywhere. Tuberculosis germs can live in the lungs and in some other parts of the body.

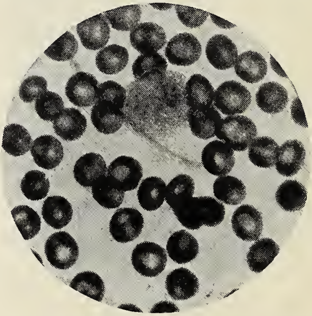
When you are ill, one of the first things a doctor does is to examine your throat.

When the germs have reached a place where they can grow, they prepare for battle. First of all, they increase their number. You remember that this happens very rapidly. Some kinds of bacteria can grow to full size and divide in twenty minutes. But they cannot grow and multiply without food, and they must live where they can get the kind of food they need. That is why some of them can live only in certain parts of the body.

After disease germs have multiplied in your body for some time, you begin to know that they are there. They make poisons in your body as they grow and divide. These poisons get into your blood and are carried all through your body. You feel sick.

Your head may ache, your eyes may be red, and you may have a fever. Your body machine is out of order because disease germs are disturbing it.

Growing and multiplying and giving off poisons would be easy for germs if they did not find enemies in your body. What are these enemies? Your blood is partly made up of white blood cells, and these white cells are powerful enemies of germs. Since blood flows everywhere in the body, these germ fighters are everywhere in the body, too. Whenever germs enter your body through the skin, through the air, or with food you eat, the white blood cells gather at the place where the germs are and begin to kill them. If you keep yourself well and strong, there will usually be enough white blood cells guarding it to kill the germs. These cells have often kept you from getting sick by killing disease germs that had entered your body.



In among these red blood cells you can see one white blood cell.

Your body machine has still another way of fighting the disease germs that attack it. Certain cells are able to make chemicals that enter the blood to fight the germs. Some of these chemicals kill germs.

Some weaken the germs so that the white blood cells can kill them more easily. Others destroy the poison that germs make.

Scientists have discovered ways to help your body make these protective chemicals, even though you are not ill. Have you ever been vaccinated for smallpox? Almost every boy and girl in your school probably has been. When you are vaccinated, the doctor puts a liquid into your body that causes it to manufacture these chemicals. They stay in your body and keep you from getting sick with smallpox. The chemicals last for about seven years; then you should be vaccinated again. The liquid that is put into your body for the purpose of manufacturing these protective chemicals is called a *vaccine*.

Other kinds of liquids put into the body go right to work fighting the germs and their poisons. These liquids are called *serums*. A serum will cure or prevent some diseases, such as diphtheria and scarlet fever.

* * * *

1. Why do germs make us sick?

2. Name two things that help keep germs from getting inside our body.

3. Of what use are your white blood cells?

4. When were you last vaccinated for smallpox? Do you need to be vaccinated again?

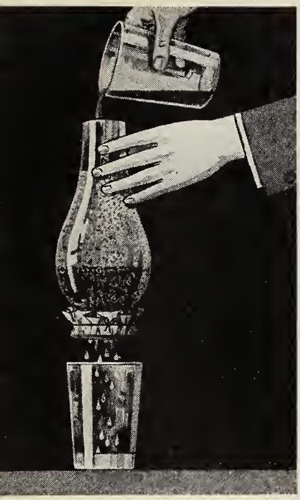
5. What should be done to cuts in the skin to prevent infection?

How can we keep disease germs from spreading?

Many states put up signs like this along the road at streams, springs, and wells where there is pure water.

A TOWN once used this sign to advertise itself to travelers. "Millville is the most sanitary town in the state." Do you know what is meant by *sanitary?* It means that the town was as clean and as free from disease germs as the people could make it. Suppose you were planning to make your town a very sanitary place in which to live. What would you do?

First, you would probably think of all the ways that germs are spread. Then you would think of ways to stop this spreading. You have learned that water, milk, and food can spread disease germs if they are not clean and pure. What can be done to keep them pure? The water you drink may come from a lake or from a river. Suppose it comes from a very muddy river. Animals have lived and died in it, and their bodies have decayed in it. Dirt can get into the water all along the river banks. If there are towns or villages on the river banks, disease germs from people who are ill may get into the water. How can this dirty, germ-filled water be made safe for drinking?



You can find one way of purifying water by doing an experiment. You will need a glassful of muddy water, a lamp chimney, an empty glass, a piece of cloth, some clean sand, and some clean gravel. Tie the cloth over the bottom of the lamp chimney or fasten it securely with a rubber band. Pour some of the coarse gravel into the chimney until you have a layer about 3 inches thick. Then put in sand until it is about 2 inches from the top. Hold the lamp chimney directly over the empty glass while someone pours the muddy water into the chimney. Examine some of the water after it has come through the chimney into the glass. Then pour the water through the chimney again. Is the water clear?

This way of taking dirt out of water is called *filtering.* But do not drink the water you have filtered, because it may not be pure, even though it looks clear. When water is filtered for a town or a city, it

This water is being sprayed into the air so that sunlight and fresh air may help purify it.

runs through much more sand than you used. In city filtering plants there are big beds of deep sand and gravel that take dirt and some of the disease germs out of the city's water. Of course, such filtering plants have to be cleaned regularly.

Another way cities purify water is by spraying it into the air. Disease germs do not live well in sunshine and fresh air. When the water is sprayed into the air, the sunshine and the oxygen can kill the germs. But the surest way to make water pure is to add germ-killing chemicals to the water. A gas called *chlorine* is most often used for this purpose. A very small amount of chlorine in a thousand gallons of water is enough to kill the harmful germs.

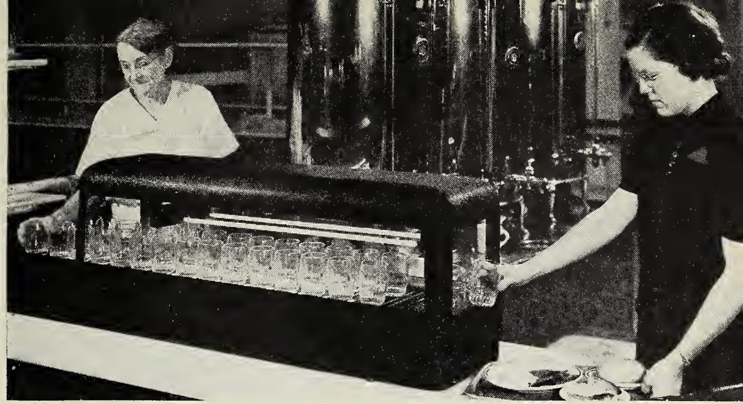
Many cities use a combination of these ways to make their water supply pure. The water is tested every day, usually several times each day and night, to be sure that the harmful germs have been taken out. Do you know how often your drinking water is

Clean barns, clean cows, clean workmen, and clean containers are all necessary to protect you against disease germs.

tested? Water may also be purified by boiling it. Of course a city cannot boil all the water it uses. But you could use this method in your own home.

You have seen that purifying the water is one of the important things in making a town sanitary. You know, too, that milk and other foods must be kept clean and free from germs. Do you know in what ways this is done? Have you ever visited the dairy farm where your milk comes from? If the farm supplies you with safe milk to drink, then you will see a clean barn, with clean cows, workmen, and milk containers.

The owner will make sure that his cows are healthy. Dairy cattle are frequently tested to see whether they have a disease, and the cows that are not healthy are killed. If the milk goes from the farm to a central dairy, the dairy, too, must always be clean. In your sanitary town you would not allow



These drinking glasses in a restaurant are being run through a cabinet where germs are killed by a kind of electric lamp that has just been invented.

milk to be sold from a farm or a dairy that could not pass regular inspections for cleanliness.

Another very important thing that is done to milk by the dairy is *pasteurizing* it. Louis Pasteur discovered this way of keeping milk pure. When milk is pasteurized, it is heated to a temperature of about 144° F. and kept at that temperature for a half hour. This kills all harmful germs. Many cities do not allow milk to be sold unless it has been pasteurized.

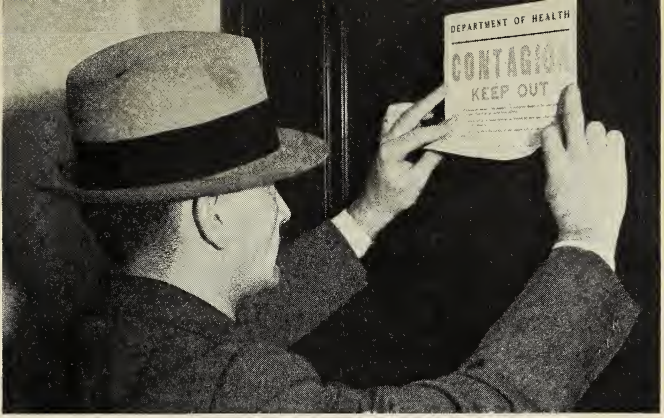
What would you do about restaurants and other places that handle food? Every restaurant should be inspected to see that the kitchens and the food are kept clean and the dishes properly washed to kill germs. The dishes should be washed in hot, soapy water, and then rinsed with clear, hot water. The food must be kept cool so that it will not spoil, and

Do you have a clean-up day every year in your town?

flies must be kept away from the food. Should the waiters and cooks pass inspection, too? Why?

Of course you know that every dirty place where flies could breed should be cleaned up. The dirt and rubbish in the streets and parks should be gathered and burned. The people of this town should keep their garbage pails covered, and the garbage should be collected and either burned or buried.

But your plans for a healthful place to live must include more than keeping the town clean. Whenever anyone gets a disease that can be carried from one person to another, there must be certain rules to stop the spread of the disease. If any one has diphtheria, measles, whooping-cough, smallpox, or some other contagious disease, he should be kept from other people. If the sick person does not go to a hospital, a sign should be placed on the door of his



Different towns use different signs to show that someone in the house is ill with a contagious disease. What do the signs in your town say?

home. People see the sign and know that they are not allowed to enter the house. We say that the sick person is *quarantined.* He cannot leave the house until the health officer takes down the sign.

After the sick person recovers, great care must be taken to clean the house and the bedclothes. All the germs must be killed. There must be none left to give the disease to someone else.

* * *

1. What is done in your town or community to keep germs from spreading?
2. How is the milk you drink made safe for you?
3. What is done in your school-room to keep germs from spreading?
4. What does *quarantine* mean?

What can we do to keep our bodies healthy?

You have seen that people can do many things that help keep germs from traveling from one person to others. You know, too, that disease germs do get into your body. When they do, your body fights them. It fights so well that often the germs cannot stay alive, and so you do not get sick. What can you do to help your body in this fight?

The best protection against disease is a healthy body. There are several things that you can do to help keep your body healthy. The following "tips on keeping well" were published in a daily newspaper at a time when there was an epidemic of influenza. Do you know why each of these hints is important and how it will help you to keep well?

1. Stay away from people who have influenza; stay out of crowded rooms full of coughers.
2. Eat healthful food.
3. Drink plenty of water.
4. Breathe fresh air.
5. Exercise in the fresh air.
6. Get enough rest and sleep.
7. Get plenty of sunshine.
8. Keep your body clean.

The first rule, of course, is an important one. When there are many cases of influenza or colds, it is best for you to stay away from theaters and other public gatherings. If you have a sore throat, a bad cold, or

Here is a good lunch: Milk for building body cells, especially the bone cells; fruit and vegetables for valuable minerals that the body needs to keep itself working well; bread and butter to provide energy to move the body and keep it warm.

some other sign of illness, you should stay at home so that you will not help germs get to your classmates. You should always cover your nose and mouth with your handkerchief when you cough or sneeze.

Now look at the other "hints." Would you be healthy without good food to eat? Your body needs food for three reasons: First, you know that you need food to grow. Your body grows by adding millions of new cells to itself. The food you eat is the material from which the body makes these new cells. Another way in which the body uses food is for repairs. As you work, play, and think, cells in your body

Vegetables do many things for the body. Some of them supply energy to move the body and to keep it warm. Beans, peas, cabbage, and celery give minerals that help the body grow and that help its parts to work well.

are being broken down. These must be built up again. Food is the material that the body uses for rebuilding them.

The third reason why the body must have food is that it uses food for power, just as a steam engine uses coal. The coal is burned to make the steam power that turns the engine's wheels. In your body the food is united with oxygen from the air you breathe. This chemical change gives you the power to move, to work, and to play. This change also makes heat to keep your body warm. Because the food you eat supplies power and heat for your body, we say that it gives you *energy*.

You can understand from this that "healthful food" means food that will build cells and that will give you energy. What kinds of foods will do these things? Meats, fish, and milk are foods that help build new cells. Milk is especially valuable for building bones and teeth. Butter, fat meat, nuts, cream, and cheese are foods that give us energy. Potatoes give both energy and warmth. Do you see why you must eat meat, vegetables, and fruits, and drink plenty of milk in order to keep healthy?

When your body uses food, there are waste materials that the body must get rid of promptly. If these are allowed to stay in the body, they make poisons that get into the blood and lower its power to fight disease germs. Drinking fresh water is one way to help get rid of wastes promptly.

Why must you have plenty of fresh air to keep well? You need the oxygen from the air to join with your food to give you energy. When you breathe deeply, you help your body get the oxygen it needs. Then the air goes down into every part of your lungs, and most of the old air comes out. If you do not breathe deeply, only a little fresh air goes in, and only a small amount of the old air comes out. But more important still, when you breathe deeply, every part of your lungs is used. This helps prevent disease germs from attacking parts of the lungs that are not used.

Can you tell why exercise helps keep you healthy? When the blood goes through the body faster, as it

In this school the boys and girls have a rest period on cots out in the sunshine and fresh air.

does when you exercise, it helps clean out the body. It acts something like a strong stream of water on a street that is being washed. Rapidly moving blood carries the waste materials away from the various parts of the body, and it carries food and oxygen into all parts of the body. Your blood cannot do its work of carrying oxygen and waste materials and of fighting disease germs if you allow it to become sluggish.

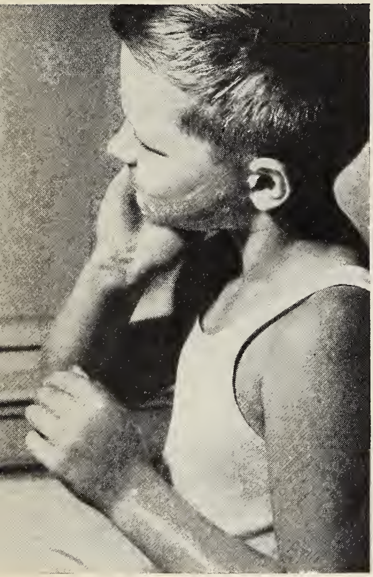
You have seen that working the muscles is very important in keeping a healthy body. But resting them is important, too. Why do we need sleep? The body needs sleep so that it can repair itself after a day of exercising and working. Many of the cells in your body are broken down when you exercise. They need to be repaired, and new ones must be made. New cells are made, and the old ones are repaired while you rest.

There is another reason why you should rest. While you exercise, the cells work hard and give off waste material. So much waste is made that your body cannot take care of it. When you rest and sleep, the blood has time to carry away the waste from the cells and to get itself ready for the next day.

If you will think about your experiment with the "bacteria gardens," you will understand another way in which you can help your body to stay healthy. Do you remember that you planted one of these gardens by placing fingers on it? Did bacteria grow in this garden? Where did they come from? Keeping your body clean is one of the most important things you can do to keep well. A clean body helps keep germs from gathering and beginning their work. Here are some rules for keeping clean that a science class made.

1. Brush your teeth both morning and night.
2. Keep your finger-nails clean.
3. Always have a clean handkerchief in the morning.
4. Wash your hands and face and comb your hair before every meal.
5. Take a bath at least twice a week. Use plenty of warm water and soap.
6. Always take a shower bath at school after you have played hard in the gymnasium.

Do you know why it is a good idea to brush your teeth every night and morning? When you eat, bits of food get between your teeth. If the food stays there very long, it decays; then tiny holes begin to appear in your teeth. Such places are fine homes for germs. There they can get plenty of food to help them grow, and soon they give off poisons into your body. If you go to a dentist soon enough, he will find the holes while they are still small. He uses a drill to grind out the decayed part of the tooth and then fills the hole with material that will harden. A tooth treated in this way is no longer a place where germs can grow easily.



Have your teeth been examined this year? Have you ever had your teeth cleaned by a dentist? He can clean places that the toothbrush cannot easily reach; then your teeth are not so likely to decay.

Why do you suppose keeping the skin clean is important to the health of your body? You know that when you exercise, your body gives off perspiration. Perspiration is a liquid that has waste materials dissolved in it. Every day your body gives off a large amount of this liquid through your skin, even though you may not feel it. Some of it goes into your clothes. Some of it stays on your skin. The liquid evaporates and leaves the solid materials on your skin. Germs often live in this dirt, where they are ready to enter your body through any tiny opening in your skin. Does this tell you one reason for taking baths frequently? You cannot always tell whether the skin is clean just by looking at it. But if there is dirt on your skin, it is carried away by soap and water. Why do you think that it is important to take a shower at school or at home after you have played hard?

Some of the perspiration that the body gives off soaks into your clothing. It is most likely to get into the clothes that you wear close to your skin; so it is important to change your clothing often and to bathe often. In summer, when you perspire more freely, it is even more important that you bathe and change clothing often.

The rule about washing before every meal is also an important one. You can easily understand why if you think of all of the things you have handled since you last washed your hands. All of these things may have had dust and dirt and germs on them. Your hands have perspiration on them, too. When you think of this, it is easy to understand why it is important to use soap and warm water on your hands and face before eating.

Now that you have read these pages, what additions do you think are needed to the rules that the science class made for keeping clean?

1. How many of the rules on page 347 have you followed today? Why do you think they are important?

2. What does exercise do for the body?

3. What are three very important reasons for taking frequent baths?

Questions to Answer

1. For which of the following diseases would you be quarantined? Measles, scarlet fever, heart disease, diphtheria, smallpox. Why would you be quarantined for some diseases and not for others?

2. Tell two ways in which bacteria are alike and one way in which some of them are different from others.

3. Tell at least three important ways in which you can keep germs from entering your body.

4. How does the body fight disease germs that have succeeded in getting inside it?

5. Describe four ways in which disease germs can be spread and tell how they can be kept from spreading.

6. Do you think that exercise helps keep you healthy? Why?

Things to Find Out

1. Find out how the water you drink is made pure.

2. Ask a doctor or your school nurse to tell you more about vaccination and other treatments that prevent diseases.

3. Find out what the Board of Health in your community does to prevent sickness.

4. Find out how mosquitoes once stopped the building of the Panama Canal and what was finally done about them.

5. Make a list of good habits that help you to keep your body well.

6. Visit the dairy that supplies you with milk and find out how the milk is kept free from germs.

7. Find out what diseases are carried by animals and which animals carry them.

8. Find out for what diseases the people in your town are quarantined.

UNIT NINE

RTY OF KILLAM ... JUN 12 1940 ... SCHOOL

HOW DOES MAN TAKE CARE OF LIVING THINGS?

ONE AFTERNOON the girls and boys in the science classes of the Oakwood Schools went to the county fair. The next day each was to report the most interesting or surprising exhibit he had seen.

Harry said that the most interesting exhibit he saw was the display of the Greenleaf Dairy Company. "It showed how the dairy barns are cared for and how the milk is bottled," said Harry. "The part I liked best was the description of how cows are tested to find out whether they are healthy."

Lucille reported that the most surprising thing she saw at the fair was at the Maple Grove Farm's exhibit. This exhibit showed samples of farm plants and gave the number of bushels of different crops raised each year on the farms of our country. "I copied down some of the figures," said Lucille. "In the United States we grow almost 500 million bushels of potatoes, more than a billion bushels of corn, and 500 million bushels of wheat in a year when the crops are good. There were samples of more than seventy different kinds of farm products at the exhibit."

"I liked the garden club exhibit that won the prize for the best flowers and vegetables," Jane told the class. "The people in charge there had a lot of lantern slides. These showed the garden before the soil was ready for the seeds. Then they showed how the prize garden was planted, how it was taken care of, and how the flowers and vegetables were harvested."

This boy and this girl are proud because their hens won prizes at the fair.

As you study this unit, you will see what problems a farmer has to solve as he raises his plants and animals. You, too, will have these same problems if you have a garden or take care of pets. If you live in a city, perhaps you can visit a farm. Of course if you live on a farm, you will already know some of the things that the unit tells about, but you will learn some new things about farm plants and animals, too.

If you do not live on a farm, you will be surprised to learn how much of a scientist the farmer must be. His work is very important, because he raises the plants and animals that we need for food.

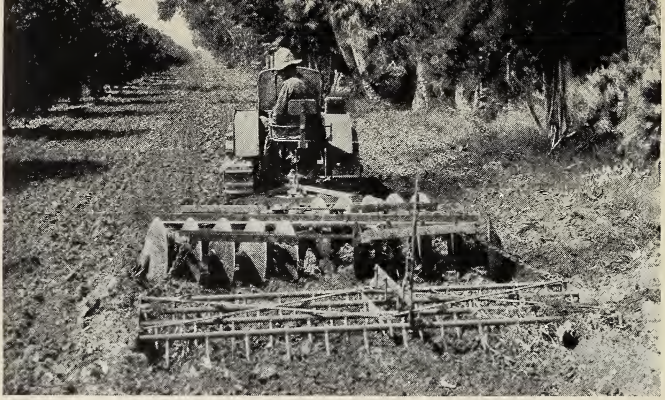
The blades of the plow cut through the layers of tough roots and tightly packed soil.

How is soil made ready for planting?

BEFORE FIELDS or gardens are planted, there is much work to be done in preparing the soil. If you have ever helped plant a garden, or if you have visited the country in spring, you will know something about getting soil ready for planting.

First of all, the soil must be loosened and broken up. To do this, the farmer first plows his fields. Sometimes the fields are plowed in late summer or early fall, and sometimes they are plowed in the spring. Of course, one reason for loosening the soil is to make it easier to plant the seeds down in the soil where they will grow best.

There is another important reason for breaking up the soil. After it has been broken up and loosened by a plow, the water from rains can easily soak down into the earth. Plants need this water to help them



grow. If the ground is hard, much of the water drains away into streams and lakes instead of soaking into the earth. When fields are plowed in autumn, the fall rains and the water from the melting snows soak into the ground instead of running off.

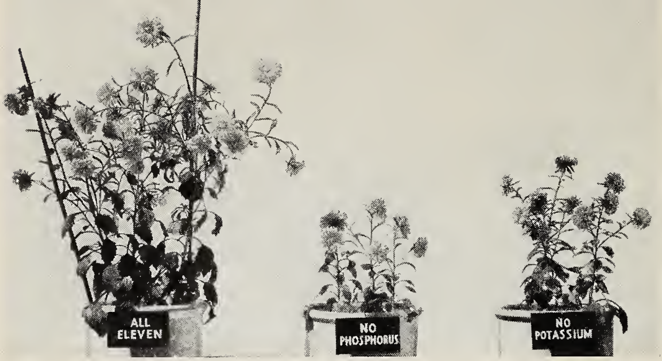
After a field has been plowed, the large chunks of soil must be broken into smaller pieces, and the soil must be smoothed over. Breaking the soil into small pieces is called *harrowing* the soil. In the spring you may see farmers using machines or implements like the ones in the picture. The implement nearest the tractor is a disk *harrow*. Can you see how it will cut into the soil and break up the pieces? Sometimes the harrow is attached to a plow. Then the soil is both plowed and harrowed at the same time.

If you can visit an up-to-date farm or a store where farm machinery is sold, you will be surprised at the many different kinds of machines used by the farmer in getting the soil ready for planting.

A field may be plowed and harrowed and ready for planting, but still a good crop may not grow. In order to grow, plants must have some very important materials. Most of these materials are minerals to use in making their food, and the plants get them from the soil. Plants need calcium, phosphorus, potassium, sulphur, iron, and other minerals. Plants must get these minerals from the soil. If the soil does not contain these minerals, plants cannot grow.

Plants are good at subtracting, and they are good at adding, too. They take away minerals from the soil all the time they are growing, and they can add minerals if we let them. If we let the plants die and decay, the minerals that are in them go back into the soil to make foods for new plants.

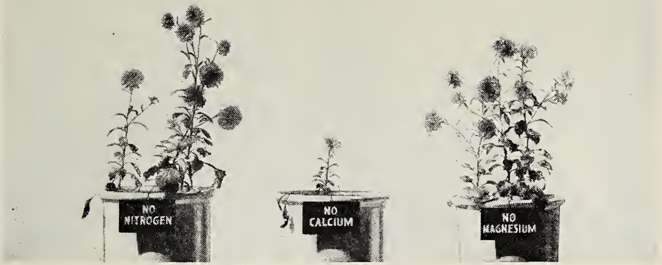
But on our farms and in our gardens we usually do not let plants add minerals to the soil. We harvest the plants and use them for food for ourselves and for our animals. When a farmer raises corn or potatoes or wheat in the same field for several years, the minerals are used up. First they are dissolved by the water in the soil; then they soak into the roots of the plants and are used to make the plants' food. Every year when the crops are harvested, more of the minerals are taken from the land. After a time there are not enough minerals left in the soil for another good crop. Then a fresh supply of the minerals must be put back into the soil.



Do you remember that everything in the world is made of one or more *elements?* Scientists have found by experiments what elements are needed by plants to help them grow. They have found that the necessary elements are nitrogen, phosphorus, sulphur, boron, potassium, calcium, magnesium, iron, carbon, oxygen, hydrogen, manganese, copper, and zinc. The pictures on these two pages show one way in which scientists have discovered that plants need these elements. In this experiment eleven different elements were tested. In one pot the aster plants were given all eleven elements. In each of the other pots one element was left out of the soil.

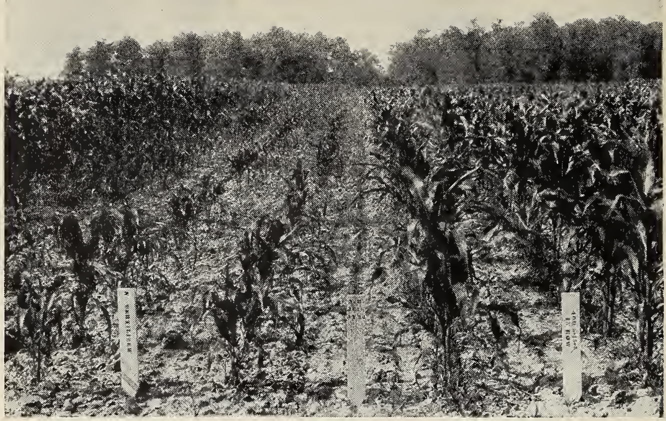
Every state has one or more Experiment Stations, where a farmer can send a sample of his soil to be tested. That is, chemical tests are made to find out what elements are in the soil. From this test the scientist can tell the farmer what materials he needs to add to his soil to grow better crops.

The elements needed by plants are contained in



materials called *fertilizers*. There are many different kinds of fertilizers. Animal manure is one. It is a good fertilizer because it contains nitrogen, phosphorus, and potassium. It is often put on lawns or gardens or around trees and bushes in the fall. During the fall and winter it decays, and the valuable materials are dissolved by the rain and the melting snow; then they soak down into the soil, to be used by plants.

There is an experiment that you can do to show how important it is to fertilize the soil. Plant some seeds in two flower pots. Use soil in which plants have been grown for some time. Use the same kinds of seeds in each pot, water them equally each time, and be sure to treat them exactly alike. When the plants appear above the soil, add some fertilizer to one pot. The proper kind of fertilizer can be obtained from a florist. Be sure and follow the directions so that you will add only the right amount of fertilizer. Watch to see which pot of plants grows better.



Part of this cornfield was not fertilized. Can you tell from the size of the corn which part was given fertilizer?

Fertilizers help plants grow better, but the right kind and amount of fertilizer must be used. If this is not done, you may injure, rather than help, your crop. It is wise to consult an expert on fertilizers before you decide which fertilizers to use.

If you live on a farm, you know that farmers do not plant the same crop year after year in the same field. They have found that the yield of a certain crop will become smaller and smaller year after year if this is done. One reason why the crops become poorer each year is that a certain crop may need a large amount of a certain element. Corn, for example, takes a great deal of nitrogen from the soil. If corn is planted in the same field year after year, the minerals containing nitrogen are soon all used up.

But clover, soy-beans, cow peas, and alfalfa actually add nitrogen to the soil. These plants are called *legumes*. So it is common practice to *rotate* legumes with other crops; that is, corn is planted in a field for a year or two, and then cow peas, alfalfa, soybeans or clover are planted for a year or two. In this way the amount of nitrogen in the soil can be kept up.

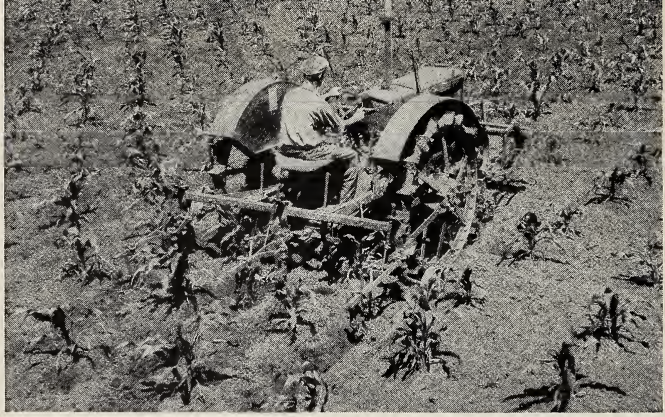
1. Give two reasons why farmers plow and harrow their fields.
2. Why are farmers careful not to plant the same crops in the same field year after year?
3. Does a good farmer put the same kind of fertilizer on every field in his farm? Why?

How are growing plants cared for?

After the farmer has plowed the ground, fertilized it, and planted the seeds, his work is only partly done. He is busy for many weeks taking care of the growing plants. Think of the things that growing plants need. You know that they need food material, water, light, and the right amount of heat. The farmer has to help his plants get some of these things.

Many crops, such as corn, beans, tomatoes, and potatoes, must be *cultivated* all the time they are growing. To cultivate the soil means to keep it loose. There are three important reasons why the soil around many growing plants must be kept cultivated.

Weeds are always fighting to get food materials and



water from our garden and farm plants. Cultivating the soil uproots the weeds and helps keep the field free from these enemies.

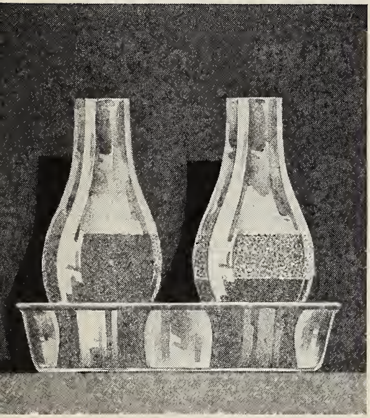
The machine that farmers generally use to keep the soil loose and free from weeds is called a *cultivator*. Study the picture on this page and notice the small blades or shovels on the cultivator. As these blades move through the soil, they loosen the soil and lift the weeds out of the ground. Small fields and gardens are often cultivated by a small machine much like the farmer's big machine. It is called a *hand cultivator*. The picture on the next page shows what a hand cultivator is like.

Another reason for loosening the soil is to allow air to get down to the roots. Plants need oxygen for the same reason that animals need it. They need oxygen so that they can use their food to grow. The roots take oxygen from the air that enters them.

The third reason for keeping the soil loose around growing plants is that the soil must be kept from drying out. All the time the plants are growing, they must have water. Here is an experiment that will show you how cultivating helps keep moisture in the soil. Dig some soil from a garden and sift it through a flour sieve. Set two lamp chimneys in a flat pan. Pour enough fine soil into one of the lamp chimneys to fill it half full. Be sure that you pack the soil down firmly as you put it in this chimney.

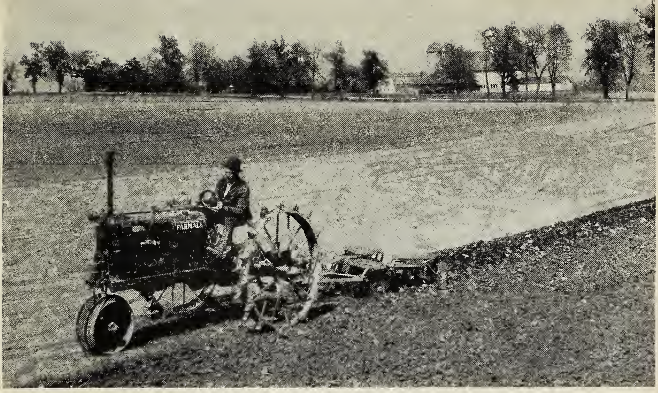
Now pour some of the fine soil into the other chimney and pack it firmly until the chimney is about one-third full. After you have done this, add enough loose soil to fill it half full. Then the soil in the two chimneys will be exactly alike except that the top soil in one is much looser than the top soil in the other. Your experiment will look like the picture on the next page.

Next pour water into the pan so that it can reach the soil in the chimneys. Watch the water. In which chimney does the water reach the top first? After the water reaches the top, it evaporates into the air. Watch the soil in the two chimneys for several days. In which chimney does the soil dry out first? Now do you begin to see how a farmer can keep the water that is in the ground from getting out too fast?



The loose soil in one chimney holds the water longer than the tightly packed soil in the other chimney. You know that cultivating loosens the top soil. Your experiment shows you that this keeps the soil from losing the water so quickly.

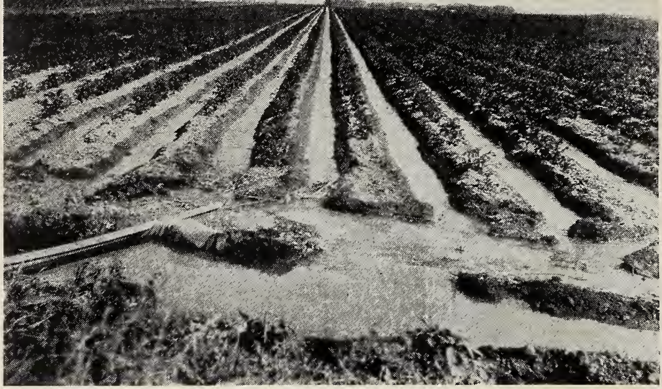
You remember that plants take minerals from the soil and change them into food. But plants cannot get these minerals unless they are dissolved in water. Dissolved minerals go through the tiny root-hairs of plants into the roots, then up the stems and into the green leaves. So, one of the important problems that a farmer has to solve is to make sure that there is plenty of water for the plants he is growing.



Can you see why this farmer is harrowing his field?

In many parts of our country there is enough rain and snow to provide water for our farms and gardens. But this water may come at a time of the year when the crops are not growing. The farmers must then try to keep this water in the ground so that plants can use it as they need it. You know now how a farmer can keep some of the water in the soil. Farmers usually cultivate their field crops soon after a rain. If the summer is dry and the plants need all the water that is in the ground, they cultivate often.

In some regions of our country there is not enough rainfall to grow any crops. In these places the farmers must get a water supply in some other way. Perhaps you live where water is brought to the land. Great areas in the western part of our country use water from mountain streams that are fed by melting snows and by rains. The streams are made to flow into large reservoirs where the water is stored and used as it is



needed. From these large reservoirs the water is carried in ditches or pipes to the fields. When farm lands have their water brought to them in this way, we say that the land is *irrigated.*

On this page is a picture of an irrigated farm. The water for irrigating this large potato field has come from a river. From the river ditches or canals lead to the farms for miles around. Each farmer who wishes to use water for his crops has a head-gate that lets water from the canal run into a big ditch leading to his farm. This big ditch supplies many smaller ditches all over his farm. The water is turned into the ditches only when it is needed.

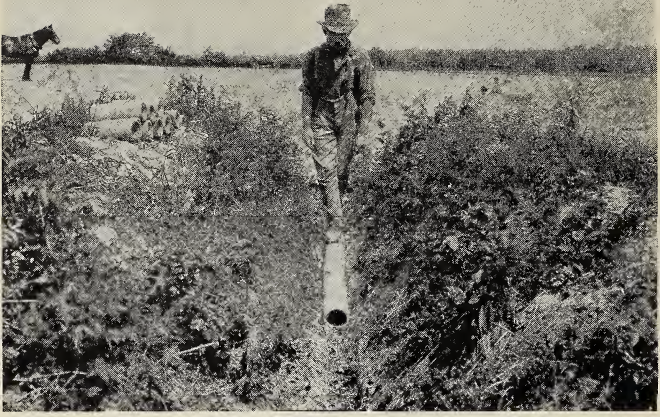
Sometimes irrigation is necessary only during the driest part of the year. Then water is often pumped from wells in the ground and is sent through ditches to the farm crops. Without irrigation Utah could never have become an important farming state. Nevada, Arizona, Colorado, Idaho, and New Mexico are some of the other western states that depend on irrigating systems to grow their farm crops.

Providing a supply of water is often one of the farmer's hardest problems, but sometimes parts of his land may have too much water. What happens to his plants then? If you do the following experiment, you will discover something about the farmer's problems when his land has too much water.

Select two plants of the same kind and of about the same size. Plant them in flower pots that are made of the same material. Each of the flower pots should have a hole in the bottom for drainage. Put pebbles or broken pieces of an old flower pot over these holes before putting in the soil.

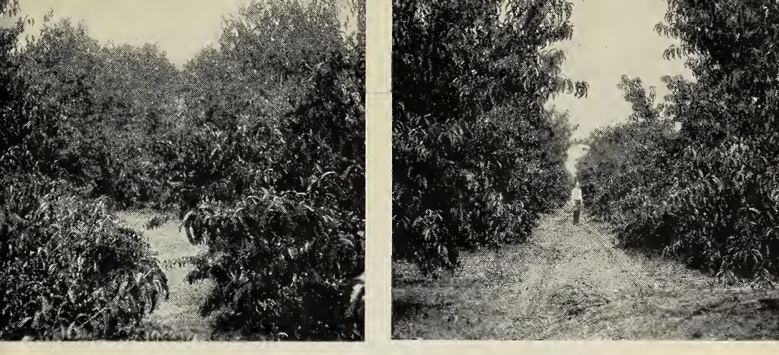
After the plants are growing well, plug the drainage hole in the bottom of one of the flower pots. Put the same amount of water on each plant every day for several weeks. What difference do you notice in the way the two plants grow? Why does the one with the open drainage hole grow better? What is happening to the one in which the water is standing? You already know that every part of a plant needs air. When the ground is full of water, air cannot reach the roots of the plant; so the plant will soon die.

Unplug the hole in the flower pot. What happens to the water that has been covering the soil? If the plant is not dead, watch it for several days and see how it begins to grow again.



This experiment shows that too much water on plants is as bad as not enough; so the farmers sometimes need to get rid of water. If one of the fields on a farm is much lower than the other fields, water drains into this low field. After heavy rains water may cover it and kill the crop. Do you know how a farmer can solve the problem of too much water? Perhaps you will say, "He can dig ditches and let the water drain off." Farmers do dig drainage ditches to carry water from the land. But ditches are likely to let some of the good land wash away, and they take up space that is needed for growing crops. They also make places for weeds to grow and spread over the fields.

The picture on this page shows the best way to get rid of too much water. The farmer has dug a ditch about three feet deep in this field, and in the ditch he is placing *tile*. The short pieces of tile are laid together



Before the trees in this orchard were pruned, many parts of the trees could not get much sunlight.

to make a long tube through which the water can run. The pieces of tile are not joined tightly together; so, after they are covered up, water from the ground seeps into them at every joint and is carried away. At the lowest end of the field they empty their load of water into a pond or a ditch. The force of gravity makes the water run downhill. In this way the extra water is carried off, instead of standing on the soil as it did in the flower pot in your experiment.

You have already learned how the farmer supplies food for plants and how he provides water for them. But do you know how a farmer can help plants to get enough sunlight?

Many farm crops, such as potatoes, corn, and beans, are planted in rows far enough apart so that their leaves will not shade each other too much. Planting crops in rows also keeps plants far enough apart so that they do not take water and food materials in the soil from each other.

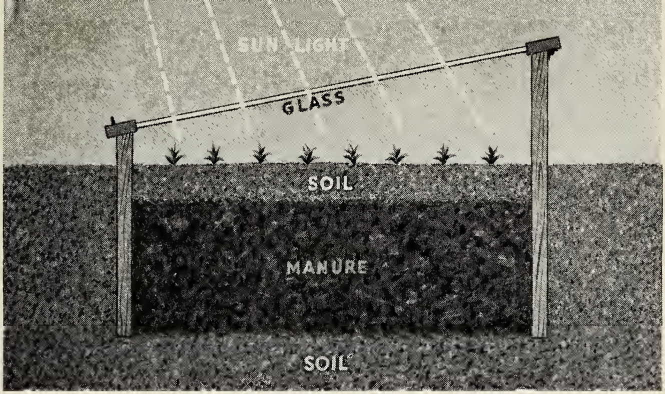
If you have ever noticed an orchard of apple, cherry, or peach trees, you may remember an important thing that fruit-growers do to provide plenty of sunlight for their plants. Have you ever seen workmen cutting branches from fruit trees? This is called *pruning* the trees. In pruning, some of the smaller branches are cut off so that there will be enough sunlight for those left.

This young peach tree has been pruned so that it will have strong branches and large fruit.

Pruning also helps the plants grow larger fruits and flowers. The roots of a tree or shrub can take in only a certain amount of food material. When some of the smaller branches and buds are cut off, there is more food material for branches and buds that are left growing.

Have you ever gone to a fair and noticed some flowers or fruits that were especially large and beautiful? Very probably, when the plants were young, the buds were all pruned off, except the bud at the end. All the strength of the plant went into this one bud; therefore it grew into a very large fruit or flower.

How do you think that farmers and gardeners help



provide proper temperature for their plants? Gardeners who raise early vegetables and flowers keep them from freezing until the warm days come by starting them in *hotbeds* or in *cold-frames*. Study the picture of a hotbed on this page. The gardener first dug a hole about two feet deep. Then he filled this hole with manure to a depth of about eighteen inches and covered the manure with good soil. Over this soil he put a glass cover that looked just like a big window with little panes of glass in it. Then the gardener planted seeds close together in the soil.

The warmth in a hotbed comes from two places. When the sun shines, the light passes through the glass and warms the soil. The warm soil then warms the air in the hotbed, and the glass cover keeps the warm air from getting out. Warmth also comes from the manure under the soil. The manure decays, and as it decays, a chemical change takes place. This chemical change makes heat, which warms the soil above the manure. So the plants that are growing in the hotbed are kept warm by both the sun and the decaying manure. Some hotbeds are even heated by electricity.

Another way to keep plants at the right temperature in early spring is to start them in a cold-frame. A cold-frame looks much like a hotbed, but there is no manure under the soil. The sun shines through the glass and warms the soil and the plants.

Of course you know how important *greenhouses* are. Because these houses are heated, plants can grow in them when it is very cold out-of-doors. Some greenhouses cover acres of land, and large quantities of vegetables and flowers can be grown in them.

1. Give three reasons for cultivating soil.
2. Why must water soak into the soil before it can be used by plants?
3. Explain two things the farmer does to provide his plants with enough water to grow.
4. What happens if water stands for several weeks in a field of corn? Why?

How can we protect plants from their enemies?

AFTER WEEKS of getting the soil ready for planting, more weeks of planting, and many days of cultivating, the farmer may say, "Now if the chinch bugs don't eat my wheat, if the corn borers don't

There was not much left of this farmer's corn when the grasshoppers had finished eating it.

get into my corn, and if the potato beetles don't eat my potatoes, I'll probably have a good crop!" Corn borers, potato beetles, chinch bugs, cotton boll-weevils, cutworms, grasshoppers, and dozens of other kinds of insects eat the leaves, stems, flowers, roots, and fruits of the plants that we need for clothing and for food for ourselves and our animals.

Killing these hungry pests not only takes the farmer's time, but it costs him money. If you plant potatoes in your garden, you are almost sure to have potato beetles feeding on the vines. If you plant tomatoes, you will be lucky if tomato worms do not eat the plants before you even know that any insects are on them. If your garden is located in some parts of the United States, a swarm of grasshoppers may pay it a visit. When they have finished their visit, your garden may not have even one green leaf left!

Do you know that every year insects do more than two billion dollars' worth of damage to grains, fruits, vegetables, and other farm crops in our country? Farmers spend millions of dollars fighting insect pests. Tons of insect poison are used every year.

So many aphids are feeding on this grapevine that the stem looks almost black.

Scientists are of great help to farmers in their war on insects. Scientists study these harmful insects to find out where they live, what they eat, where they lay their eggs, how they change as they grow, and what their other habits are. The scientists have examined insects carefully to find out how they eat. You, too, can do this. Get a weed or any plant that has *aphids* on it. Aphids are often called plant lice. Examine one of the aphids with a magnifying-glass to see how it is eating. Do you see a little tube piercing the leaf or stem of the plant? With this tube-like mouth the aphid sucks sap from the plant, just as you suck lemonade through a straw. Insects that eat in this way are called *sucking insects.*

We cannot kill sucking insects by poisoning their food, because their food comes from inside the plant, where poison cannot reach it. We can kill them, though, by putting a poison on the plant that will touch the bodies of these insects. This poison gets into their breathing holes and smothers them. Because this poison must touch the insect in order to kill, it is called a *contact poison*. One good contact poison is tobacco extract. This is poisonous to people and should therefore be handled with care.

If you want to kill the harmful aphids that you have just examined, buy a contact poison. Follow the directions on the can and fill a spray with some of this liquid. Then spray the plant on which the aphids are feeding and watch them. You will be surprised to see how quickly they are killed. The gray triangular squash bug that feeds on squash, cucumber, and melon vines, the stink bug that is found in the berry patch, and the chinch bug that damages wheat and corn are other sucking insects.

Many insects get their food in a different way. If you examine a grasshopper when it is eating, you will see it bite a piece out of a leaf with its large jaws. Its jaws move from side to side as it chews this bit of leaf. Insects that get their food in this way are called *chewing insects*. They, of course, can be killed by putting poison on the part of the plant they eat. This kind of poison is called a *stomach poison*. Some stomach poisons commonly used to kill harmful insects are lead arsenate and calcium arsenate. These pow-

You can see from the leaves of the tree that these caterpillars are chewing insects.

ders may be dusted on the plants, or they can be mixed with water and sprayed on. Some chewing insects are cabbage worms, Mexican bean beetles, potato beetles, tomato worms, and tent caterpillars.

One of the best poisons to use in killing insects is *rotenone*. Rotenone will kill both chewing and sucking insects because it is both a contact and a stomach poison. Rotenone is not poisonous to people and to other warm-blooded animals; therefore it can be used on vegetables. Because tobacco extract and lead arsenate are poisonous to people, they should be used very carefully. The only time these poisons can be used with safety is when they are put on parts of the vegetables just beginning to grow or that are not used for food.

Some insects can be destroyed in the spring or fall by plowing up their homes. When you studied how the grasshopper grew, you learned that the mother grasshopper laid a little case full of eggs in the ground. You can easily see what plowing would do to these egg cases.

There is another enemy of plants that farmers and gardeners spend much time destroying. These enemies grow in the soil with the farm crops, and they use food materials, water, and sunlight that the crops need. They are plants that man does not use, and we call them weeds. Unless the farmer keeps busy, weeds take so much food from the soil that there is not enough left for his plants.

If you have a lawn, weed pests will keep you busy. One of the commonest weeds that spoils the appearance of a lawn is crab grass. This is a coarse grass which makes the lawn look a dirty brown in the fall. It is difficult to get rid of crab grass. About the best way is to dig it out by hand when it is very young. This can be done easily because it has short roots. Crab grass grows from seed each year, and if it is prevented from making seeds, it will not appear the next year. Dandelions and chickweed are two other pests of the lawn. The best way to get rid of them is to pull them up. Both of these plants make seeds all summer long, and you must be constantly watchful to pull them before the seeds are ripe.

Weeds come up in your garden even though you do not plant the seeds. The seeds have stayed in the

At the left is a picture of crab grass. Can you see why it is sometimes called finger grass? Chickweed, shown on the right, is often a pest in the garden and field.

soil all winter, and they sprout as soon as the soil is warm and the spring rains come. Examine some weeds to see how many seeds they grow and how easily these seeds are scattered. Then you will understand why it is necessary to kill weeds before they blossom and make seeds. After the seeds have been made, the wind may carry them for miles. It is no wonder that weeds spread so rapidly and keep coming up where you do not want them. The roots of some kinds of weeds stay in the ground year after year. Such weeds must be pulled up and burned, for if their tops are cut off, new shoots will soon grow.

If it were not for the birds, man could never win his fight against weeds and insects. Every hour of the day birds are gobbling weed seeds and insects as fast as they can pack them away. Many people never think about the value of birds in protecting our crops. To find what birds are eating, scientists have examined the stomachs of dead birds. The stomach of one quail contained 300 smartweed seeds, 500 sorrel-grass seeds, 700 mercury-weed seeds, and 1000 ragweed seeds. And even this large number was not a full day's food for the quail, for of course only the undigested seeds could be counted. Actually, a quail eats many times this number of weed seeds in a single day. It has been estimated by one scientist that tree sparrows in Iowa eat 875 tons of weed seeds a year.

Birds eat vast numbers of insects, too. A flicker was found to have over 1000 ants in its stomach. The stomach of a night hawk contained fifty different kinds of insects, such as ants, Colorado potato beetles and other injurious beetles, and several kinds of mosquitoes. Millions of insects are destroyed every day by birds. If these insects were allowed to live, they would soon destroy our food supply.

1. Why is it necessary to know the habits of insects that eat plants?
2. How do weeds harm garden crops?

How can you grow a garden?

DO YOU WANT to have a garden of your own this spring? If it is not possible to have one at home, perhaps you can have a school garden. You will find that gardening is a lot of fun. Of course you

At this school in Cleveland, Ohio, the boys and girls have small garden plots. Notice how well the plants are growing.

will get more pleasure from having a garden if it is one you are proud of.

One of the first things in making a garden is to decide what you are going to raise. Do you want to have a vegetable garden, a flower garden, or a garden for both flowers and vegetables? And what kinds of each do you want? The first step in making a good garden is to draw the plan of it on paper. In this plan you will draw lines for the rows of the different plants that you are going to raise. These rows will be different distances apart, depending upon the sizes of the plants when grown.

Seed catalogs contain information that will help you plan your garden and also will help you select vegetables or flowers to plant. Naturally you should have the tall plants at the back of your garden and the low ones in front. You might have your garden like one of the plans shown on page 381.

FLOWER GARDEN

(*Size:* 10 feet by 4 feet)

FOUR O'CLOCKS		9″
MARIGOLDS	ZINNIAS	12″
DWARF NASTURTIUMS		12″
SWEET ALYSSUM		9″
		6″

Front of garden

VEGETABLE GARDEN

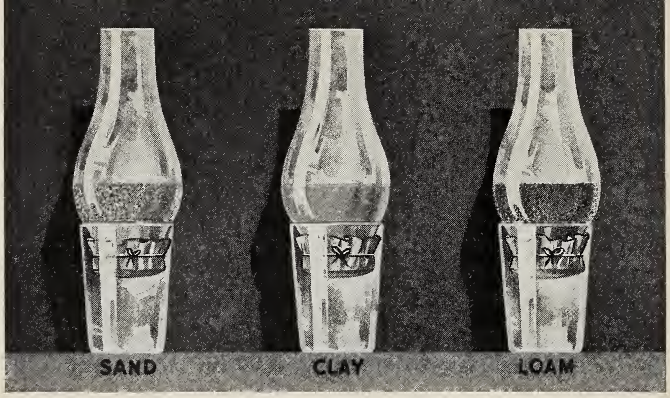
(*Size:* 4 feet by 10 feet)

TOMATOES	18″
LETTUCE	9″
SWISS CHARD	9″
CARROTS	12″
CARROTS	12″
BEETS	12″
BEETS	12″
EARLY TURNIPS	12″
BEANS	12″
RADISHES	9″
	6″

Front of garden

It is better to start with a small garden. You will be surprised at the amount of work needed to keep even a small garden in good condition. A garden ten feet long and four feet wide, or one that is twelve feet long and five feet wide, is a good size. Select a sunny spot where the drainage is good.

After you have selected a suitable place for your garden, you will want to examine the soil to see whether it is mostly clay, sand, or loam. Loam, you remember, is a mixture of sand and clay with some decayed plant and animal material in it. You can easily tell one kind of soil from another. Moist clay is sticky; and dry clay is hard, almost like a rock. Sand is gritty and falls apart easily, even when it is wet. You are probably asking, "What difference does it make whether the soil is clay, sand, or loam?" The experiment on the next page will help you discover the answer.



Get three lamp chimneys and tie a piece of cloth securely over one end of each. Also get a sample of sand, a sample of clay, and a sample of loam. Be sure that each of the soils is dry. If they are moist, you can dry them in a warm oven. Pour the sand in the first chimney, the clay in the second chimney, and the loam in the third. Press the soil down firmly in each. Then put each chimney in an empty drinking glass as shown in the picture. Use the cups that contained the soils, and fill three glasses with water.

Next, have three members of the class each pour a glass of water into a chimney at the same time. Watch to see which soil lets the water through first. Does the water run through the sand first? Then after awhile does the water come through the loam? What happens in the chimney containing clay? Does the clay hold the water?

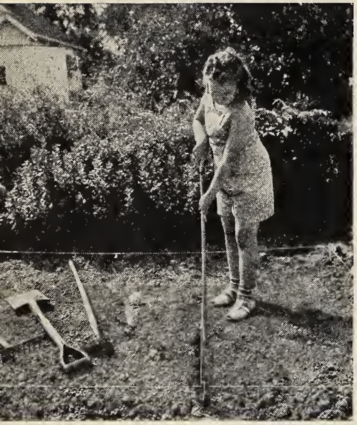
This experiment tells why it is important to know about the kind of soil in your garden. If the soil is mostly clay, it will not be satisfactory. Clay would hold water, and this would make the roots rot. Then, too, clay sticks together so tightly that the roots could not get air. On the other hand, water runs right through the sand. The experiment shows that loam soil will keep water better than sand, but will drain better than clay soil.

There is something else that you will need to know about the soil. Perhaps you have heard of *sour soil.* In *Discovering Our World, Book Two*, you learned how to test for acid with litmus-paper. When you put blue litmus-paper in vinegar or lemon juice, the paper turned red. Try putting some moist soil from your garden on a strip of blue litmus-paper. If the paper turns red, your soil has acid in it. Many plants will not grow well in acid, or sour, soil. Lime or ground-up limestone worked into acid soil will make the plants grow.

After you have made a plan and have decided where you are going to have your garden, the next thing is to get the soil ready for planting. You must loosen the soil with a spade or a spading fork. Then break up the lumps with a hoe or rake and finally level the ground with a rake. You cannot do this when the soil is too wet. Hit a lump of soil with a spade to test it. If it crumbles, the soil is just right to work; but if it sticks together, it is too wet.

When the soil is prepared for planting, you have a question to decide. Is this soil rich enough to grow a good garden? If not, you know that you can add materials to it by using a good fertilizer. Spread the fertilizer over the garden and hoe it or rake it into the soil so that soil and fertilizer are well mixed.

Then follow your plan in laying out your garden. You can easily have straight rows of plants if you will use a garden line. Just tie a stake at each end of a string that is a little longer than the row in your garden, and you have made a garden line. Put the stakes in the ground so that the string is tight and right over where you wish to have a row of plants. Then with the handle of a hoe or with a stick make a furrow directly under the line made by the string.



Margery is using a garden line to guide her in making a straight furrow.

And now comes the fun of planting your garden! Look at the seeds you are going to plant. Are they of different sizes? Large seeds should be planted deeper and farther apart than small seeds. But do you know just how each kind of seed should be planted? Beginning on the next page are some directions that will help you.

To plant little seeds, such as carrots and lettuce: With the handle of a hoe or with a stick make a little furrow only about three-fourths of an inch deep. Remember to use your garden line to help you make a straight row. Take a few seeds at a time and scatter them evenly in this furrow. The seeds must then be carefully covered with about one-fourth inch of fine soil. Press the soil down hard with your hand all along the row. You do this so that the moist soil will be sure to touch the seeds.

To plant medium-sized seeds, such as beets and radishes: These should be planted in a furrow about one inch deep. Scatter them in the furrow and then cover them with about one-half inch of soil. Then press down hard on the soil as you did in planting the small seeds.

Jane is planting beet seeds by carefully scattering them in the furrow.

To plant large seeds, such as beans and peas: Make a furrow about two inches deep and put the seeds about one and one-half inches apart. Then cover them with a little more than an inch of soil. The soil must also be pressed down with your hand.

It is also important to know when to plant different kinds of seeds. The seeds of radishes, spinach, lettuce, carrots, and beets will sprout and grow in early spring while the weather is still cool. These seeds can be planted early. But the seeds of corn, beans, cucumbers, and squash should not be planted until the weather is warm, for they will not sprout when the weather is cool. Seed catalogs will generally tell you the best time for planting the various kinds of seeds.

The seeds of some plants like tomatoes, peppers, cabbages, or egg-plants will not sprout until warm weather comes. But it takes these vegetables so long to grow large enough or ripe enough to eat that they should be started early in the spring indoors or in a hotbed or greenhouse. Then when all danger of frost is past, you can set these plants out in your garden. This is called *transplanting*. To transplant a plant, you must make a hole big enough to hold the roots as the girl in the picture has done. And then you must be sure to pack the soil down firmly all around the plants.

After the plants have grown several inches above the ground, you may find that there are too many of them. If the plants are crowded closely together, none of them can get enough food material from the soil, enough water, or enough sunlight to grow into healthy plants. They must, therefore, be *thinned* just as soon as they are large enough to handle. Although you may not like to pull out many of the plants that have come up, you know that this must be done to give the others room to grow.

Notice that David is hoeing in just the right way. He is "following the hoe."

Now that your garden is planted, what must you do to take care of it? Perhaps it will be well if you read again pages 361-363 to find the reasons why the farmer cultivates his crops. How can you cultivate your garden? You can use a hoe for this work. You should go down each row of plants, chopping out the weeds and loosening the soil. You may even need to get down on your hands and knees to pull out the weeds that are growing close to the garden plants. Remember that you must be sure to pull up the roots of some weeds, such as crab grass and pigweed. And of course you should get these weeds out of your garden before they go to seed.

The handful of weeds Ted has pulled up from his flower garden shows that it has not been weeded for sometime.

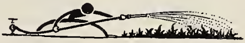
Loosening the soil with a hoe will ordinarily keep enough moisture in it for your plants. But if it is an unusually dry season, or if you have very sandy soil, then you will probably need to water your garden. Water it well, but not more often than once a week if you give it a good soaking. This should be done in the evening so that the water will have a chance to soak down to the roots of the plants before the heat of the sun causes much of the water to evaporate.

You will get better results if you prune the tomato plants in your garden. Notice the little shoots that grow out sideways from the stem. These should be broken off with your fingers. Every few days examine the plants and cut out or pinch out these side-shoots before they have grown much. You will find that the tomatoes will be larger on plants that are well pruned. If you have flowers in your garden, you will be glad to know that most flowers bloom better if they are picked often.

Sally is spraying the leaves of her zinnia plants with a stomach poison. How does she know that chewing insects have done the damage?

In caring for your garden, here is a question that you will soon be asking, "How can I get rid of the insects that are eating my plants?" A good plan is to watch the insect eat to find whether it is a chewing insect or a sucking insect. If you find holes eaten in the leaves of your garden plants, you will know that chewing insects are at work. They can be killed by spraying their food with a stomach poison. If sucking insects are causing the damage, you will need to dust or spray your plants with a contact poison. Read again pages 375-376, to be sure you know about these different kinds of poisons.

It is fun to plant a garden, and it is fun watching it grow. But perhaps the most pleasure is gathering the flowers and vegetables. It will be interesting to know just how much of every crop you raise. You might keep a garden diary to help you keep track of the things you take from your garden.



1. Give two reasons why a garden is planted in rows.
2. Why is it necessary to thin some crops?
3. If your soil is too sandy for a good garden, what could you do to make it satisfactory?
4. How can you keep moisture in your garden?
5. Tell how to plant small seeds, medium-sized seeds, and large seeds.

How can you take care of pets?

Do you know how to keep your dog, your cat, your canary, your rabbit, or other pet well? Pet animals are like human beings in some ways. They must have enough food of the proper kind to keep them well. They must have a home which will protect them and keep them comfortable. They must be protected from injury and disease. Furthermore, they must be kept clean or be provided with ways of keeping themselves clean.

Since pets differ greatly from each other, you must learn how to take care of the particular kind of pet that you have. Many books have been written about taking care of pets. Here we can tell you only a few of the things that are necessary to know.

Washing your dog is one of the ways to help him keep well and happy.

Of course you know that there are many kinds of dogs. All dogs, however, have teeth which are so constructed that they can tear and cut meat. Their stomach and intestines are made so that meat can be easily digested. For this reason, meat should make up a large part of the dog's daily meals. Either raw or cooked meat may be used.

Care must be taken with meat containing bones. Chicken bones and chop bones are likely to splinter or break into small pieces that may cause the dog to choke. A dog should also be fed some vegetables. After a dog is over a year old, it is usually better to feed it only once a day. This is best done at the time of the evening meal for the family.

If your dog is allowed to run and play with strange dogs, you must be on the watch for a disease called *distemper*. This disease is likely to result in the death of your dog. There are several symptoms to watch for in this disease. One is loss of appetite. Another is a fever. Another is red and inflamed eyes.

Your dog will feel more comfortable if you brush out burs and other things that may stick to his coat.

If you suspect that your dog has this disease, you should take the dog to a veterinarian. He can use a serum which will prevent your dog from having distemper. Since the disease is more likely to be fatal in young dogs, it is best to give the serum to the dog when it is a puppy.

Cats are not so friendly as dogs, but they make interesting pets. They can eat many kinds of foods. Milk, bread, fish, vegetables, ground beef, and prepared cat food can be fed to them. Cats are usually fed twice a day, and it is a good plan to vary the kind of food at each meal. The cat is somewhat like you: It does not like to eat the same kind of food day after day. Perhaps you have noticed that cats sometimes eat grass. Grass or some leafy vegetable, such as lettuce, seems to be a necessary part of a cat's food. Such a vegetable should be included in one meal every day.

Canaries are attractive pets because of their cheery song. Since they must be kept in a cage, we must provide one that is large enough to allow them to get as much exercise as possible. The cage should be placed where the bird can get plenty of sunlight. Canaries like to take baths. After a bath it is easy for them to catch cold. For this reason the cage should not be hung in a draft. The best food is the kind that is especially prepared for canary birds by people who know what these birds need. This can be purchased at pet stores.

There are of course many other interesting pets to have. Goldfish, tropical fish, waltzing mice, guinea pigs, white rats, turtles, and baby alligators are a few of the many kinds of pets. Each kind of animal has a certain structure and certain habits. You must supply it with the proper food and the proper home, or it will die.

You can learn many things about animals if you watch how they behave. When you get a pet, you must take care of it properly. Remember that your pet animal is dependent upon you for the right kind of food and home. You must meet this responsibility.

1. Why must different kinds of pets be fed different kinds of food?

2. How could you tell whether you are feeding your cat or dog too much food?

3. Report to the class what you have learned about taking care of some pet at home.

Questions to Answer

1. What are the chief farm crops raised in your community?

2. How do farmers kill the insect pests that live on the crops in your community?

3. If you have a garden at home or at school, tell some of the ways this unit helped you in making it and taking care of it.

4. How would farming and gardening be different if scientists had never helped farmers and gardeners?

Things to Find Out

1. Visit a greenhouse and find out how the plants are cared for.

2. Find out what the chief farm crops of your state are.

3. Try to visit an experimental farm or find someone to tell you about such a farm.

4. Visit a good dairy farm and see how the animals are taken care of.

5. Try to find out how young chicks are cared for.

6. Learn the names of the common weeds and insects that are garden pests.

7. If there is a hotbed or a cold-frame near your school, find out just how it is made.

8. Watch the newspapers and bring clippings to class about such items as: insect pests and their control, gardening, pruning, and weed control.

9. Try to visit an up-to-date farm to see some of the things described in this unit.

10. Study a rainfall map of the United States. Find some regions that need to be irrigated. Find regions where there is sufficient rainfall for crops.

UNIT TEN

HOW CAN WE CONSERVE THE MATERIALS AND LIVING THINGS OF THE EARTH?

THERE ARE more than 2250 million people in the world today, and everything they have comes from the earth. This whirling, spinning globe of rock, soil, water, and air is a rich storehouse of materials. Some of these materials we must have to stay alive. Other materials help us live more happily and more comfortably.

Think for a moment about the things that we get from the earth. Every bit of food that we eat comes from the soil. The meat that we eat comes from animals, and the vegetables, fruits, and grains come from plants. You know that animals cannot live without plants, and plants use the minerals from the soil to make their food. So the soil of the earth produces all of the food that the 2250 million people of the world eat.

These 2250 million people also get all of their clothing and shelter from plants and animals and from the earth. From plants come cotton, linen, and rubber. From animals come wool, silk, and leather.

Sheep furnish us with wool, meat, leather, and other useful products. How do these products come from the soil?

Trees furnish the wood for houses and other buildings. Iron ore from the earth furnishes the iron and steel for skyscrapers, bridges, and other structures. Clay from the earth furnishes material for bricks. Marble, granite, and other stone used for buildings also come from the earth. Glass for windows is made from sand. Plaster for walls is made partly of materials taken out of the earth.

The millions of homes, factories, schools, and other buildings in our country are kept warm in winter by materials that come from the earth's storehouse. Every year the people in the United States burn more than 425 million tons of coal. All of it comes from down in the cellar of the earth! And coal is not the only material used for heating. Millions of cords of wood are burned each year to keep houses warm, and from thousands of wells oil flows up out of the earth to be used as fuel.

Look about your home tonight and make a list of the things there that come from the earth's storehouse. Your list will include furniture, rugs, cooking utensils, glassware, and lighting fixtures. Do not forget to look into the medicine chest and the cupboard. Everything there came from the earth, too.

If you have read these paragraphs thoughtfully, you are probably asking these questions: "Won't all of these materials in the earth finally be used up? What will people do then? Can we put some of the materials back into the earth?"

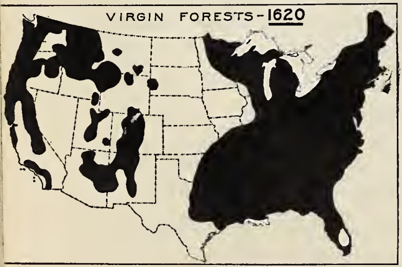
One of the most important problems that the people of the world have to solve is this: How can we use the materials in the earth so wisely that they will last as long as possible? Do you know what our country is doing to keep the materials of the earth from being wasted? Can you do anything to help conserve them? This unit will help you answer these questions and many others about the *conservation* of our materials and living things.

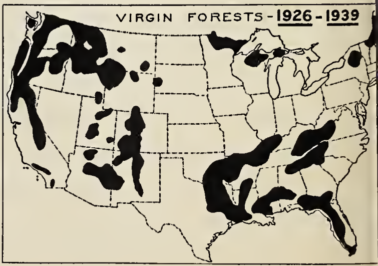
What is happening to our forests?

LOOK AT the two maps on page 400. They tell a story of what happened to the forests that covered a large part of our country since the first colonists came about 300 years ago. The black parts of the first map show how much of our country was covered with forests in the year 1620. Were there forests in your state then? Now look at the other map. The black parts show how much of the first forests are left.

Find your state on the map. Does it have any of the forests that were there when the settlers came to our country? Perhaps most of the forests that are in your state now have grown up since the first trees were taken off. You can see that most of the original forests have disappeared. In all our country today there are only about 100 million acres of forests that have never been cut over. Perhaps this sounds to you like a great number, but once there were 400 million acres of trees.

For over 300 years we have been cutting down the trees of our country as carelessly as if the supply would last forever. What have we used them for? Eight out of every ten houses in the United States


VIRGIN FORESTS-1620


VIRGIN FORESTS-1926-1939

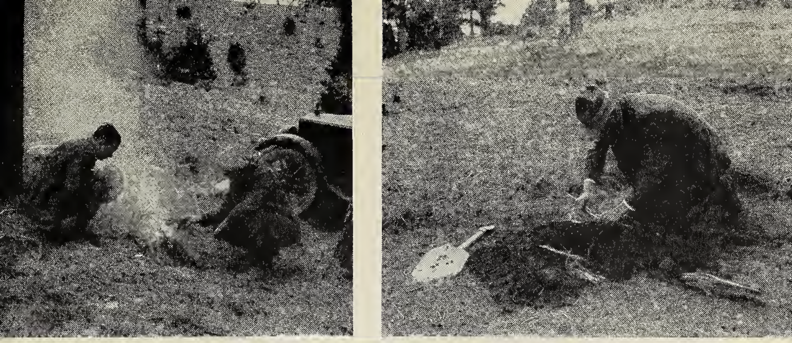
A large part of the United States was once covered with forests as fine as this one in California.

are made of wood, and nearly all of the furniture in these houses is made of wood. One-fourth of all the wood used in our country goes for heating and cooking our food. Newspapers, books, and magazines are made from wood. You will probably be surprised at the tremendous quantities of wood we use in another way. As you know, wood is used to make cardboard boxes, cartons, wooden crates, baskets, boxes, and other containers to ship things in. How much wood do we use in this way? Someone has figured that the lumber used in shipping Florida's farm products for one year would build more than seven thousand six-room houses! Remember that this amount is needed for the state of Florida alone and for *only one year!*

The railroads use a great many of the forest trees, too. Almost one hundred million railroad ties are used every year to keep the tracks in good condition. Great forests of trees are cut down to make poles for telephone wires, telegraph wires, and wires to carry electricity for power. Nearly three and one-half million new poles are used every year. These poles would make a telephone line around the world, and there would be enough poles left to make an extra line from New York City to San Francisco!

The paragraphs you have just read will give you an idea of what happens to thousands of acres of trees every year in our country. But the sad part of the story of our forests is not how we have used them. We need them, and we want to use them to make life more comfortable and pleasant. But millions of acres of fine trees have been destroyed without doing us any good at all. They have been destroyed by fire, and every year fire continues to de-

The tallest and the largest tree in a forest cannot save itself from being destroyed by fire.



The camp-fire at the left is a *dangerous* one. A camp-fire should *never* be built on top of dry pine needles or grass or near trees. The camp-fire at the right will be a *safe* one. The woodsman has cleared a place of all grass, needles, and trash, and has dug a hole in which he will build a small fire.

stroy forests in this way. The value of the trees ruined by forest fires in our country each year amounts to the enormous sum of $450,000,000.

Before man lived on the earth, there were very few forest fires. Sometimes forest fires were started by lightning or by some other natural cause. Today there are many forest fires, but only about one out of every ten is caused by lightning. Men and women and boys and girls start nine out of ten of the forest fires that cost us millions of dollars a year. It is hard to believe, but we human beings, who need trees so much, are the greatest enemies of the forests.

How do we cause all this damage? We do it by being careless. We build camp-fires in places where they should not be built. We leave the fire without putting it out carefully. Then a wind comes up, fans

Pine beetles are insects no longer than a fifth of an inch. But when an army of them moves in between the bark and the wood of a tree, they damage it by chewing small tunnels all over it.

the embers into a blaze, and blows live coals into the surrounding bushes and trees. Automobile drivers carelessly throw lighted matches or burning cigars or cigarettes out of the car into the leaves and grass by the roadside. Smokers do the same things as they walk through forests. From one little fire on the end of a match, on the end of a cigar, or on the end of a stick that was burning in a camp-fire may come a terrible forest fire that will destroy thousands of dollars worth of trees and perhaps even cost the lives of people.

But fire is not the only enemy of the trees. Another enemy is a six-legged one—the insect. Insects destroy over $100,000,000 worth of trees every year. Some of these insects live in the wood and make it worthless for lumber. Some live in the bark and injure the trees so that they soon die. Others live on the buds and leaves. Every part of the tree is likely to be attacked by insects that either kill it or make it useless to us.

Trees have diseases, too. Some kinds of diseases attack very young trees and kill them. A disease called *damping-off*, caused by a kind of fungus, sometimes spreads through a field of young trees that are being grown to replant a forest. Almost over night every young tree in the field will wilt and die. This disease does not usually attack young trees that have sprouted from seeds in the woods. It does its great damage by destroying nursery trees. White-pine blister-rust is a disease that destroys many pine trees. Many of the white-pine forests in the northwestern part of our country have been destroyed by this disease.

* * *

1. Give four reasons why we have fewer forests in our country today than we had two or three hundred years ago.
2. What is the most frequent cause of forest fires?
3. Why is it important to replace forests that have been cut?
4. What are some of the most important uses of forests?

This deep gully has already eaten into a peach orchard in Georgia. Unless it is checked, the whole orchard will be lost.

What is happening to the soil of our country?

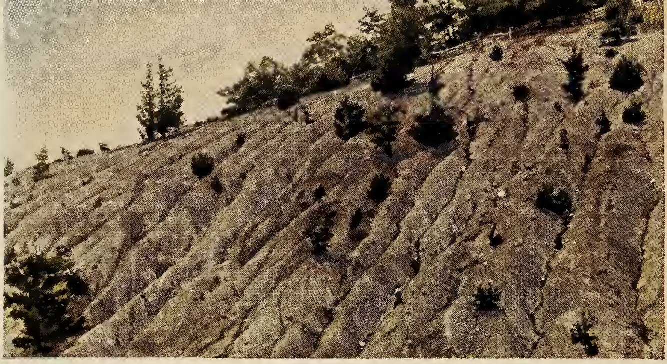
You may wonder what could possibly happen to the soil of our country. It cannot be entirely destroyed by fire, as forests are destroyed. Insects cannot kill it, and except for a little clay that we use for bricks and dishes, we do not use it up as we do wood, coal, and oil. But our soil is in danger, just the same. Millions of acres of good soil have already been ruined, so that they will not grow the plants that we need for food and clothing. Our government and thousands of our citizens are today fighting a hard battle to conserve the soil of our country. Let us see what it is that puts our soil in danger.

You already know that growing crops take minerals from the soil. If these minerals are not put back into the soil, plants cannot grow in it, and we say that the land is worn out. Thousands of acres of land in our country are no longer used for farming, because the land has been worn out. The right kinds and amounts of minerals needed by plants are gone.

You have learned that ever since the earth was formed, wind and running water have been wearing away land. This wearing away of the soil is called *erosion*, and it is one of the natural ways in which the surface of the earth changes. But this erosion of the soil is very, very slow when the soil is protected with a covering of plants. The map on page 400 shows that forests once covered much of our country, and most of the rest of the land was covered with grass. Great stretches of open country were covered with the thick sod of prairie grass.

Do you know how the trees and the grass help keep the soil from washing away? Let us see what happens when rain falls in a forest. If you have ever walked under the trees in a thick woods, you know that the soil is soft and spongy. Decaying leaves and twigs are scattered about over the ground. Usually the forest floor is covered with a layer of this material that is several inches thick.

When rain falls in a forest region, it first strikes the leaves and then drips from the leaves and branches to the ground. This makes the water fall more gently upon the land than if the land were bare of trees. The soft, spongy soil in a forest is full of tiny holes, and as the water drips from the trees,



it easily soaks into the soil instead of running off in a stream.

A thick covering of grass also helps keep most of the water from running off the land after a heavy rain. The grass breaks the fall of the rain and makes it strike the ground more gently. Therefore very little of the water runs off into streams. Even when the rains fall or the snows melt on hilly ground, the water flows off slowly, and much of it sinks into the soil if the ground is covered with grass.

Now let us see what happens when forests are cut down and grass lands are plowed. The picture on this page shows what happens. Can you tell what has made the gullies on the bare slope? Here the rain fell on the hard, bare ground. It could not soak in very fast; so it began to flow downhill in little streams. Down the hillside it went, carrying the soil with it and digging gullies in the hillside. On a steep hillside it is easy to see that water can carry soil away. In the same way it can carry soil from a gently

sloping field if the soil of the field is unprotected by plants. Then the farmer can no longer use the land either because the rich top soil with its minerals has been carried away or because the field is full of gullies.

The soil in the picture on this page has been moved, too, but it was not carried by water. Wind carried it, and it is good top soil that was blown away from near-by farms. Hundreds of farms in the western part of our country have been ruined because wind erosion has carried away the rich top soil. Wind cannot blow soil that is covered by forests or thick grass, but where the forests have been cut and the grass lands plowed, the wind can ruin thousands of acres of good farm land. The greatest damage is done in places where there is little rainfall, because dry soil unprotected by plants is easily blown by the wind. In some parts of our country several inches of the soil have been blown from the fields.

You have seen how forests have disappeared and how land is being robbed of the rich soil needed for growing crops. Other materials that we need are disappearing from the earth, too. We take more than 425 million tons of coal out of the mines in the United States each year. Year after year trainloads of iron ore are taken from the earth, too. Copper, silver, and other metals are also used in great quantities from the earth's storehouse. Many mines in the United States have been abandoned because all of the metals have been taken from them.

* * *

1. Explain how changes in the earth's surface affect farming.
2. Cutting down trees and plowing grass lands are both harmful to soil. Explain why.
3. Why is it especially harmful to farmers if the top soil is carried away?
4. What does *erosion* mean?

What can we do to conserve our trees?

EACH YEAR we take huge quantities of materials from the earth's storehouse. No new supply of coal is being formed in the earth today, and no new oil supply. No new iron ore or copper is being made in the earth. We are cutting nearly twice as much timber every year as we are growing! What will happen if we keep on taking things from the storehouse of our earth?

Foresters have cut the diseased, broken, and full-grown trees from this forest. This gives those that are left a better chance to grow into tall, straight trees.

Some of the materials cannot be put back; others can. For example, we cannot put new supplies of coal and oil into the earth, but we can plant new forests, and we can put minerals into the soil to make it good for growing crops. We can also do something to keep the water and wind from carrying the soil away. Do you know what is being done in your state to keep up our supplies of the materials that we need?

One of the first things that we can do to conserve our forests is to use them wisely. No one believes that we should go without wood just to save the forests for some future use. We need lumber, and it must come from the forests, but we should make the best use of these forests. For example, when large forest trees are cut down, care should be taken to see that

A sprinkling system keeps beds of two-year-old pine trees in a Wisconsin state nursery from drying out.

they do not fall on the young trees growing near. If the young trees are not injured, they will grow and be ready for use later. When logs are hauled out of the forests, many young trees are killed unless the lumbermen are very careful. This is a wasteful use of forests, and it must be stopped if we expect to have a supply of lumber in the future.

When logs are cut and trimmed, the branches are often left in the woods. They interfere with the young trees that are growing, and when they become dry, they increase the danger of fire, for a match thrown into this dry brush will quickly start a big blaze. One way, then, to conserve our forests is to take care of the forest areas that are cut over so that young trees can grow to make new forests.

These men are planting young Douglas fir trees in a national forest in Colorado.

Another way to save our forests is to plant young trees. Many places that were once covered with trees are now being replanted. Every year millions of trees are started growing in nurseries in the United States. When they are large enough, they are transplanted. Many of these trees are planted on land that can never be used for profitable farming. Perhaps the land is too steep or too rocky for the plowing and cultivating needed by most crops.

If enough of these new trees were planted and if they were allowed to grow to their full size, our forest problem could be solved. That sounds easy, but it is not easy. When our young forests have started growing, often a match or a camp-fire sets fire to the woods. How can we prevent this?

The Forest Service of our national government is at work night and day all year to save our forests from burning. First, the Service tries to keep forest fires from starting. Second, it tries to stop fires when they start. Part of the job of keeping forest fires from being started can be done by your science class.

Cooking over a camp-fire is great fun. Putting out a camp-fire is work. But we cannot enjoy our forests unless we protect them, too.

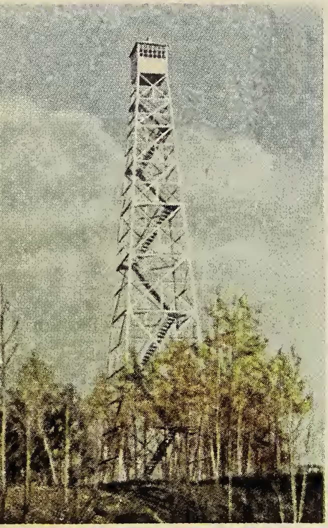
You remember that nine out of every ten forest fires begin through the carelessness of some person. How many of the pupils in your class go to the woods on week-ends or during the summer? How many of you build camp-fires? Is everyone in your family careful about matches and lighted tobacco?

The people whose carelessness starts fires in the woods were once in your school and in other schools in the United States. Some of the pupils in your science class probably go on camping trips to the woods with their parents or with groups of scouts. Of course you do not know whether anyone in your class or in your family has actually started a forest fire. Many of the people who start such a fire never know it. The fire may begin slowly, after the people have left, and it may not be noticed for a long time.

But you can be sure of one thing: If every person who went into the woods put out any camp-fire he made and every match he lighted, and if smokers were certain that no cigarette stubs or other smouldering tobacco were left on the ground, there would be very few forest fires. If every boy and girl began today to form the habit of helping to prevent forest fires, we would save millions of acres of fine trees.

To put out a camp-fire, you should first pour plenty of water on it. To be especially careful, you should cover it with earth, too.

Stopping a forest fire after it has started is no easy matter. One thing is very important: If possible, fires should be discovered while they are still small so that they can be more easily put out. The Forest Service has worked out ways of finding small fires. In



the great forest areas of our country hundreds of towers like the one in the picture have been built. Forest-fire lookouts in these towers can see for miles across the country, especially with the help of field-glasses and telescopes. The towers are equipped with telephones, and when a ranger sees a small column of smoke rising from somewhere in the forest, he reports the fire by telephone to the nearest ranger station and tells the rangers there where the fire is located.

At each station there are maps to show the roads or trails that will lead to the place where the fire is. The maps also show where the ponds and streams are that can furnish water to help put out the fire. Weather reports tell the rangers how fast the wind is blowing, how it is likely to change, and whether rain may be expected to fall.

When the report of a fire comes to the ranger station, the fire-truck is ready to leave for the fire at once. Truck loads of men follow the fire-truck, and there are trucks to carry food, camp equipment, first-aid tents, and other materials. The fire may be several miles from the ranger station and in a place that is hard to reach. If the weather is dry, the fire may spread over many acres of forest before the men arrive, and it may take days to put the fire out. So the men need to take food and other equipment with them.

In some of the large forests in the state of Washington fire-trucks that run on tracks are used.

As you know, insects are another enemy of our trees. Some kinds of insects feed on the newly formed layers of wood, located just under the bark of the tree. Water goes up to the leaves through these layers of wood. When these layers have been eaten, the water cannot reach the leaves of the tree; so the tree soon dies.

Other kinds of insects feed on the leaves of the trees. You know that green leaves are the food factories. When too many of the leaves are eaten, there is no longer any place for food to be made, and the trees die. Still other kinds of insects bore into the wood of the tree. If there are enough of these insect borers, they soon make the tree worthless, because the boards cut from it will be full of holes.

The problem of keeping insects from ruining the forests is a hard one to solve. Scientists work to control insects in forests just as they do to keep insects from eating fruits and vegetables. You remember from Unit 9 that the scientists on experimental farms study how the insects live, where they live, what they eat, where they lay their eggs, and many other things about them.

Sometimes trees are sprayed with kerosene to kill harmful insects.

Insects on farms may be destroyed by spraying or dusting poison on them or on their food, but forests cover too many acres for such methods. Although airplanes have been used for spraying trees in small forests, this has not been found a very satisfactory way to fight insects. It is not a good plan to use poisonous dusts and sprays in forests, because they may poison forest animals that use the trees and other plants for food.

The most satisfactory way of controlling insects is to keep them from getting into a region of forests. There are several ways of doing this. One way is to keep insects from coming to our forests from other states or from other countries. When lumber is imported or when young trees or other plants are brought to this country, they sometimes contain insects or insect eggs. The government employs men to inspect plants and other materials that are brought to the United States, so that insects will not come in with them. Cutting dead trees and taking them out of the woods is another way of fighting these pests, for insects are most likely to live in dead trees or unhealthy ones.

TRANSPORTING
TREES AND PLANTS
PROHIBITED BY LAW
INSPECTION REQUIRED TO PREVENT SPREAD
OF INSECT PESTS AND PLANT DISEASES
ADDRESS
STATE DEPARTMENT OF AGRICULTURE
STATE CAPITOL MADISON, WISCONSIN.

Have you ever seen signs similar to this?

As you know, some kinds of insects feed on each other. When insects or other animals feed on each other, they may keep a sort of balance of numbers among themselves. Some year there will be an unusually large number of one kind of insect. Then the other kind of insect will have plenty of food, so that the next year the number of each kind will be about the same. This balance is often very helpful, for it keeps insects from increasing too rapidly and damaging the trees.

Scientists have found that sometimes natural enemies of insects may be brought into a forest to kill some of these pests. Birds are one natural enemy always ready to help us fight our insect pests.

Both the hairy woodpecker and the downy woodpecker are excellent protectors of trees. An examination of many stomachs of these two kinds of woodpeckers shows that they contained many wood-boring beetles, both adults and larvae, also caterpillars of insects that burrow into trees and ants that live in decaying wood and are particularly harmful to timber.

"It is evident" says the United States Department of Agriculture, "that the woodpeckers are great conservators of forests. To them more than any other agency we owe the preservation of timber from hordes of destructive insects."

* * *

1. What is wrong with this statement? We should conserve our forests by never cutting down any trees.

2. What can you do to: (1) keep forest fires from starting in your state, (2) help birds so that they will be able to stay alive and eat insects in forest areas?

3. How does the National Forest Service work to keep our forests from being burned?

4. How do methods of killing farm insects differ from methods of killing forest insects?

5. Why is it important to inspect trees and other plants brought to this country from other countries?

In the oil fields near Los Angeles, California, there are hundreds of wells.

How can we conserve the materials in the earth?

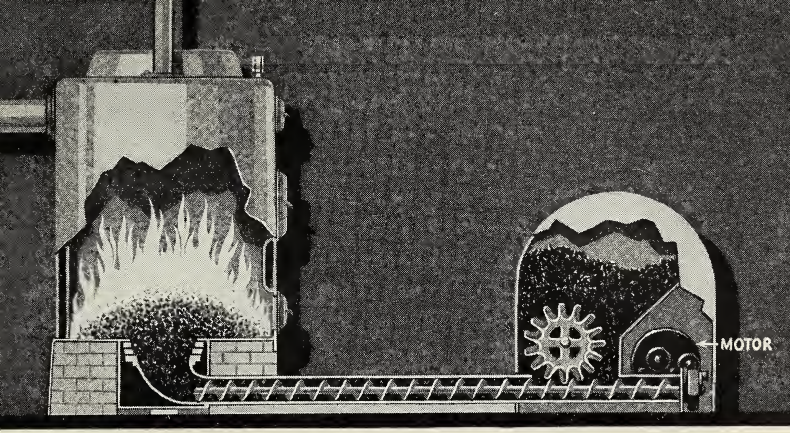
EVERY YEAR we dig out of the earth of our country about 400 million tons of coal. From the oil wells of our country over one billion barrels of petroleum flow every year to make gasoline, kerosene, oil, and other products that we need for heating and to run our engines. Will these valuable materials ever run out? Scientists say that there is enough coal in the earth to last us hundreds of years, but they are not so sure how long the petroleum will last.

What can we do about these valuable materials that are being used up so rapidly? We cannot plant new coal and oil, but there is one thing that we can do to help save our fuel supplies. We can be careful not to waste them. Scientists can help us in another way: They can experiment to find substitutes for the natural fuels that we now use and in this way make our supplies last longer. Let us see how these things are possible.

First, how can we keep from wasting our coal supply? Scientists have made important discoveries about fuels to help us get the most heat from them. You may be surprised to know that one kind of furnace may burn a ton of coal and give a much greater amount of heat than another kind of furnace. Stoves and furnaces have been improved greatly, to keep them from wasting so much heat. When heat is wasted, then of course more coal must be burned to keep a building warm.

Much fuel can be saved if people will learn how to feed the coal properly into their stoves and furnaces. Many people put too much coal on the fire at one time. When too much coal is put on, it is not all burned to give heat. Some of it goes up the chimney as black smoke. This fuel that goes up the chimney is wasted. If you wish to get the most heat from the coal you burn, you should put only a little coal on the fire at a time and put it on more often. Then all of the coal will burn, and you will get the most heat from it. Whenever you see great clouds of black smoke coming from a chimney, you know that fuel is being wasted.

An invention called an *automatic stoker* has made firing a furnace very easy and has helped save fuel in thousands of homes, apartment buildings, and



In an automatic stoker the motor turns a long screw. This pushes the coal from the bin into the furnace.

factories. It is a machine that keeps a furnace supplied with just the right amount of fuel all of the time. Stokers not only save money for the people who own them, but they help save our coal supply, as well.

Even though the wise use of our coal will help make our supply last longer, there is still no way to put more coal into the earth. So we must find other ways to help save the supply. We need coal to keep us warm, and we also need it for power to run our machines. Are there other materials that we can use to give us power? You already know that the force of running water is used to produce electricity, and you know that electricity runs many machines for us. In some parts of our country where electricity is cheap, it is even being used to heat homes and

Red clover is planted in this orchard to keep the soil from being worn away.

cook foods. Electricity, then, is one substitute that we can use to help save our coal supply. Perhaps scientists will find other kinds of fuels to take the place of coal.

You have already learned that the soil of our country is in danger. Our food plants are taking minerals from the soil, and erosion by running water and by wind is carrying the soil away. If you remember what you learned in Unit 9 and if you have read this unit carefully, you already know some of the ways to save our soil. Minerals can be put back into the soil by adding fertilizers and by planting the right kinds of crops. We cannot stop the wind from blowing or the water from flowing downhill, but we can keep the wind and the water from wearing away the soil so fast. From what you have already read, can you tell how this can be done?

Scientists have made many experiments to find

A railroad company has built rock dams in the gully to keep the water from flowing so rapidly that it washes away the banks. If the gully gets bigger, the railroad tracks may fall into it.

out how to stop the erosion of the soil. They have found that covering the soil with plants helps to stop the land from washing away. Planting trees and growing a thick layer of grass make it much harder for the water to run off and carry the land with it. Many experiments have shown what a surprising difference there is between an acre of land covered with woods and an acre of bare land. In one experiment, in one year only 115 pounds of soil was washed from the acre of land covered with trees. How much soil do you think was lost from the acre of land that was bare? You will probably not guess anywhere near the right amount. The acre of bare ground lost 112,316 pounds of soil by erosion in one year.

These scientists discovered another important thing from their experiment. When they examined

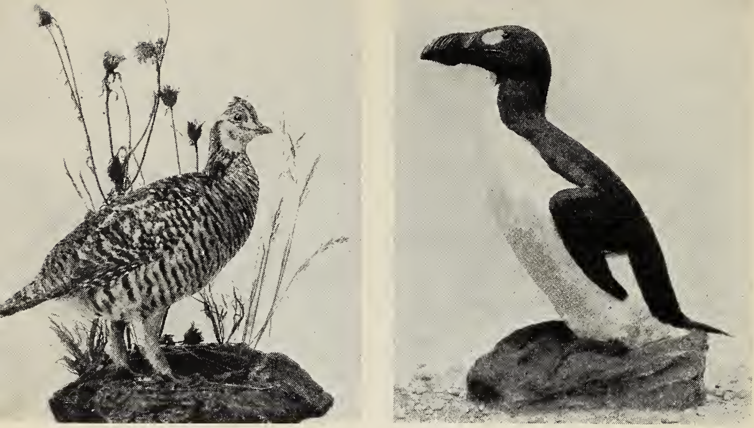
the soil that was washed away, they found that it was very rich in the minerals that plants need. Then the scientists figured how much money it would take for fertilizer to put these minerals back into the soil. They found that it would cost only five cents to put minerals back into the wooded acre of soil. But it would cost the farmer $59.15 for fertilizer to replace the minerals that the acre of bare soil had lost by water erosion in one year. So you can see that the streams of water which run off the bare land of a farmer's fields are carrying money away with them.

Such experiments as this show us that planting trees and grass will save our soil from being carried away. Of course, not *all* of the land has to be kept planted. But farmers should be sure that most of their sloping land, which is most easily washed away, is kept covered with trees or grass. Land that is not being used for farming purposes should usually be covered with some kinds of plants.

Even when it is necessary to plow up the land for farm crops, the bare soil can be protected against running water after heavy rains. In the picture on page 426 you can see how the field is being plowed. The water cannot run down this hill easily. When rain falls on the side of the slope, the ridges in the soil stop the water. There are many different ways to keep water from flowing off the land too rapidly. Sometimes small dams like the ones in the picture on page 425 are built. They hold the water and slow it up so that it cannot carry away so much soil. In experimental stations all over our country scientists are working on the problems of how to stop the erosion of our soil by wind and water.

* * *

1. Describe two ways of keeping our coal supply from becoming exhausted. How can scientists help with this problem?
2. Can you find out where coal is wasted in your school, your home, or your community?
3. How can the erosion of soil by wind and water be prevented? Do you know of any places in your state where these methods are being used?
4. Why is it expensive to a farmer when he loses the top soil from his land?



The heath hen, shown at the left, disappeared as recently as 1932. The great auk, shown at the right, vanished in 1844.

What can we do to protect our wild life?

HAVE YOU ever heard the story of the passenger pigeon? Once there were millions of these beautiful birds in the United States. They flew in such great flocks that they almost darkened the sun. Some people admired them for their beauty. Other people killed them for food or just for the sport of shooting. The birds were even caught in great traps and shipped to the city markets. Gradually they became scarcer and scarcer. Finally, the last passenger pigeon died in a zoo in Cincinnati, Ohio, in 1914. No one in your class ever saw a live passenger pigeon, and no one ever will.

There are several other kinds of birds that have disappeared from the earth because people killed so many of them. A bird called the great auk is gone forever from the earth, and so are the heath hens that once lived by the thousands in our eastern states.

Some animals, although they have not entirely disappeared, have become very scarce. For example, great herds of American bison, usually called buffalo, once roamed our western plains. When the West was settled, large numbers of the buffalo were killed for their meat and hides. In a period of a little more than ten years nearly five million buffalo were killed. In 1914 there were fewer than fifty wild buffalo left in our country, with about 1500 in captivity.

When the great forests of the United States were cut down, the homes of many animals were taken away. Birds live in trees and find safety from their enemies in thick woods. Deer, elk, and other kinds of animals also find food and protection in the forests. Beavers, mink, otters, and other fur bearers depend on the forests and forest streams for their homes and food. Some animals, like the buffalo and the prong-horned antelope, lived in great numbers on the prairies and plains of the West. When this land was settled, it was used as pasture for sheep and cattle. Then the wild animals lost their homes.

Many of our wild plants are beginning to disappear, too. Mountain laurel, flowering dogwood, fringed gentian, trailing arbutus, lady-slippers, trilliums, and many others are becoming so scarce that you may never have seen them. In your state these flowers may once have been very abundant, but people have picked them until there are only a few left.

When flowers like the trilliums and lady-slippers are picked, nothing is left but the roots. The leaves grow on the same stem as the flowers. Food is made in the leaf, and this food is stored in the roots for the next season. When the leaves are taken, food-making stops, and there is no food for the next season. Therefore the trillium should never be picked. Other wild flowers that should not be picked are: bloodroot, dutchman's breeches, fringed gentian, Jack-in-the-pulpit, may apple, mountain laurel, partridge berry, trailing arbutus, wake robin, columbine. If you leave a flower on the plant, it will go to seed. Then the next year the seeds may grow into a new plant.

A wild flower that grows on a long stem, such as the blue violet, may be picked more freely than most of the other wild flowers. In picking, however, take only a few of the green leaves and do not disturb the roots.

When forest lands are cut, some kinds of wild flowers are destroyed. Many kinds of flowers need a damp, shady place with rich soil in which to grow. A woods is just the right place for them. Cutting trees has caused many of our wild flowers to become scarce.

When wild animals and plants were plentiful, no one thought much about saving them. There seemed to be an endless supply. After a time, some of the people who were most interested in wild life became

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Many kinds of ducks have found food and shelter in this bird sanctuary in Maryland.

alarmed. They could see that something needed to be done, or many of our living things would soon disappear.

Certain people who were especially interested in protecting our bird life formed the National Association of Audubon Societies. These societies have done very important work since they were begun in 1905. For many years they have worked to protect birds, especially song birds, from being killed, and they have helped people to understand how important birds are to us. Thousands of boys and girls today belong to Junior Audubon clubs.

One of the most important things the Audubon Societies have done is to establish places where birds can live and raise their young in safety. Such places are called *bird sanctuaries*. Thousands of acres of land have been made into such homes for birds.

During the winter, in Wisconsin game refuges, food is kept at feeding stations for pheasants and other game birds.

Since the Audubon Societies started their work, our national government and many state governments have also established animal refuges and sanctuaries where animals can live and raise their young in safety. There are probably game refuges in your state. All of the national parks are game refuges.

Nearly all states now have laws that forbid the shooting of song birds. Other laws forbid killing game birds except during certain seasons of the year. Ducks, pheasants, quail, and other game birds are protected by law except for certain days or weeks of the year. Since these laws have been passed, many of the birds have increased in numbers.

Many people in our country have private bird sanctuaries where birds stop when they migrate and where they can build their nests. Sometimes these areas are very small. They may consist of bird houses, feeding-tables, and bird baths in the yard. Trees and shrubs are planted which provide seeds and fruit for the birds. Probably some of you have helped to protect birds in these ways. It is important that everyone in your class learns not to disturb a bird nest while it contains eggs or young birds. Many birds are destroyed because something happens to their nests.

Fish laws have been very important in protecting the wild life of our lakes and streams. Most states have laws that prevent the taking of fish unless they are over a certain length, depending on the kind of fish. They also have laws that prohibit the catching of some kinds of fish except during certain seasons of the year. It is not lawful to dynamite fish in streams, as was sometimes done before these laws were passed.

To help keep fish in our streams and lakes, scientists in our National Bureau of Fisheries study the habits of fish. They find out what kinds of foods different fish eat and where they raise their young.

All these jars in a Wisconsin fish hatchery are filled with muskellunge eggs.

Our national government has established many fish hatcheries all over our country. In these hatcheries fish are raised. The eggs are collected and kept at just the right temperature for hatching. After the young are hatched, they are fed and cared for by experts who know just what to do. When the young fish are large enough, they are taken to lakes and streams to replace fish that have been caught. Many state governments do the same things.

Some states have passed laws protecting certain kinds of wild flowers. It is unlawful to pick flowers in any national or state park. Many states have posted signs along the highways, urging tourists and others not to pick certain kinds of wild flowers. Unless people realize the importance of leaving some of the rarer flowers to grow and multiply, these flowers will soon disappear.

* * *

1. Why are game laws important?
2. What can your science class do to help protect wild animals and plants?

How can we conserve human life?

You have been reading how we try to save and to use wisely the living and non-living things of our country. We also have many ways of protecting human lives against the dangers that we meet every day. Perhaps you should think first what some of these dangers are.

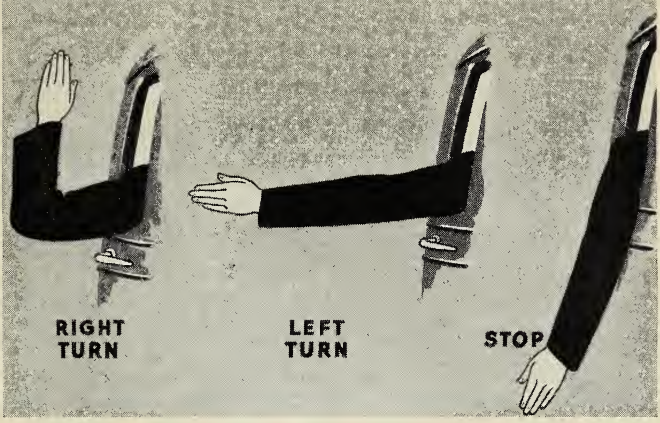
The hundreds of automobiles that carry people to and from work and on pleasure trips are a great source of danger. Hardly a day passes in a big city without several people being killed or injured in automobile accidents. Other means of transportation, such as trains, airplanes, street-cars, and boats, also cause accidents that injure or kill people.

Machinery in factories causes many injuries every year. Fires in public buildings and homes destroy human lives and injure people. Diseases spread from one person to another and cause serious results. Can you think of some ways in which we try to

If your school has a Safety Patrol, the members of the patrol help guard you against accidents with automobiles.

make the world safer against these dangers? Suppose you make a list of as many safety-helpers as you can.

To help save our citizens from injury and death, many laws have been passed. For example, in many states people must obtain a driver's license before they are permitted to drive an automobile. To obtain this license, they usually take a driving test. Their sight and hearing are tested, and they must show that they understand the rules of driving. In most places there are laws that set a limit to the speed at which a car may be driven. There are also certain signals for turning, backing up, slowing down, and stopping. People who obey the rules help prevent injury to their fellow citizens as well as to themselves.



These are the hand signals used by automobile drivers in many states. What signals are used in your state?

In many states automobiles must be inspected frequently to make sure that they are safe to drive. Brakes are tested, and if they do not work properly, they must be adjusted at once. Headlights are tested to be sure that they light the road properly and that they can be regulated so that they will not blind the driver of an approaching car. The other parts of the car are inspected also. If they are not all satisfactory, they must be repaired so that the car will be as safe as possible for both the driver and other people.

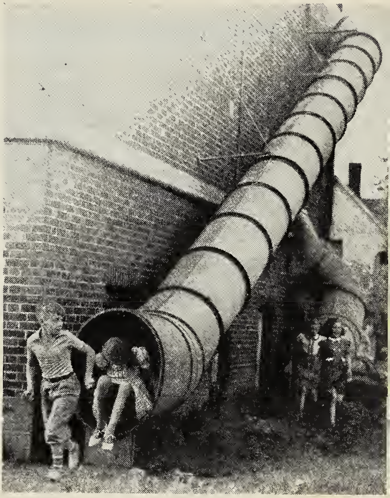
You probably know the rules you should follow in riding a bicycle or in walking on the pavement. It is just as important for you to watch the traffic lights as it is for the drivers of automobiles. Also, you should always travel in the direction from which the traffic is coming; that is, face the traffic. In this way you can see the cars that are on your side of the road. At night, if you are walking on a dark road, it is a good plan to carry a flash-light or some other light so that automobile drivers can see you.

All factories have rules for preventing accidents. The employees are shown how to operate machines in a safe manner, and are cautioned always to be careful. Special safety devices have been invented to make machines safer to operate. For example, gear wheels are covered with wood or metal guards, some parts of machinery have guards to protect the workers' hands, and electrical devices are carefully insulated.

Railways, street-cars, buses, and other means of transportation also have rules for safety. Electric signals, guard rails, and many other devices help to prevent accidents. Buses that carry passengers must stop at all railway crossings. Street-car signs caution passengers not to board cars or step from them while the cars are moving.

Perhaps you know something about the fire laws of your school and other public buildings. All such buildings must have fire exits plainly marked and lighted and must have fire-extinguishers in good working order. Buildings are inspected to make sure that there is nothing about them that might cause a fire. Fire escapes are inspected, and care is taken to make sure that in case of fire there will be a convenient way of escape. Most of our public buildings are constructed mainly of materials that will not burn. Stone, cement, steel, and other materials are used instead of wood.

In your study of Unit 8 you learned some of the things that the Public Health Department does to protect you against diseases. If you drink city water, your water supply is tested to make sure that it is pure so that you will not get typhoid fever or some other disease from germs in the water. Your milk supply is also tested, and the cows are tested to be sure that they are healthy. The meat you buy from your meat market, and the food you buy from your grocer must pass certain requirements for cleanliness before they can be sold.



Most schools have regular fire drill so that pupils will know how to use the fire escapes in case of fire.

If anyone in your community has a disease that other people can "catch" from him, he is placed under a quarantine. This protects you from getting the disease. Vaccination, too, prevents you from getting some diseases, such as smallpox. If you go to your doctor for a physical examination frequently, he helps you keep well because he can often detect signs of a disease before it is too serious to cure. You see that we have many laws and do many things that help protect us against disease and accidents.

1. Why are automobile driving laws important?

2. What must you do to get a driver's license in your state?

3. What is done in your community to protect your health?

4. Why is it important for your school to have a safety patrol or some other way to prevent accidents from automobiles?

Things to Find Out

1. Find out about the state parks and wild-life sanctuaries in your state and visit one if possible.

2. Find out which fur-bearing animals are protected by law in your state.

3. Get a copy of your state game and fish laws and discuss them in your class.

4. Prepare a talk which you think would convince your listeners that it is important to use our forests wisely.

5. If your school has a motion-picture machine, write to your State Department of Conservation for a list of films and choose some of them to be shown in your school.

6. Find out where the forest areas are in your state and what kinds of trees are in them.

7. Watch for accounts of forest fires in the newspapers. If you can do so, find out what caused the fire and what methods were used to put it out.

8. Make a set of rules that the members of your class can use for helping to prevent forest fires.

9. Try to find out whether your state is now planting new forest areas.

10. Find out more about the Audubon Societies and other groups that are organized to help save our wild plants and animals.

11. Find out about the *National Wildlife Federation* and what it is doing to protect our wild plants and animals.

12. Find the names of the birds in your neighborhood that help protect the trees by eating many insects.

SCIENCE WORDS

Can you say the word "armature"? Do you know what it means? You can tell by finding it in the following list of science words. This list shows you how to say, or *pronounce*, the science words in your book. It also helps you to know what these words mean.

The words are printed twice, just as they are in a dictionary. The second time, there are marks over or under some of the letters to show how each letter should be pronounced. The part of the word which should be accented is marked ′. Some long words have both a main accent (′) and a lesser, or secondary, accent (′).

Study the following sounds, and they will help you understand what the marks mean:

a	at, can	ē	be, me	o̤	connect, second
ā	came, face	ė	her, longer	oi	oil, point
ä	far, father	e̤	towel, quiet	ou	out, found
â	all, ball	i	it, pin	ş	nausea
ȧ	glass, ask	ī	line, mine	ţ	picture
ã	care, dare	o	rock, not	u	up, but
a̤	alone, company	ō	broke, open	ū	use, pure
ä̤	beggar, opera	ö	moon, move	u̇	put, full
e	end, bend	ô	off, song	ṳ̄	nature

A single dot under ā, ē, ō, ö, or ū means that the sound is a little shorter and lighter, as in cottage (kot′ạ̄j), reduce (rẹ̄-dūs′), and into (in′tọ̈).

a cid (as′id), a sour material that turns blue litmus-paper red.

air-pres sure (ãr′presh′ṳ̄r), the force with which air presses against objects because of its weight.

am ber (am′bėr), a hard material that looks somewhat like yellow or brown glass. Amber was formed long ago by the hardening of sticky gum from pine trees.

a me ba (a-mē′bạ̈), a very small and very simple animal.

am phib i an (am-fib′i-a̤n), an animal, such as the frog, that lives part of its life on land and part of its life in water.

aph id (af′id or ā′fid), a very small insect that lives on plants.

Arc tu rus (ärk-tū′rus), a very bright star in the northern sky.

ar ma ture (är′ma̤-ţūr), the movable part of an electrical machine.

armature coil, the wire that is wound around a piece of iron.

ar se nate (är′se̤-nāt), a salt of arsenic acid. Lead arsenate and calcium arsenate are poisons used to kill insects.

as tron o mer (as-tron′ọ̄-mėr), a scientist who studies the stars, sun, planets, moon, etc.

as tron o my (as-tron′ọ̄-mi), the science of the stars, sun, planets, moon, etc.

Au du bon (â′dụ̄-bo̤n), a scientist who studied birds (1785-1851).

ax is (ak′sis), a real or imaginary straight line around which a thing turns.

back-fire (bak′fīr′), a fire set to check a forest or prairie fire by burning off the space in front of it.

bat ter y (bat′ėr-i), a set of two or more electric cells connected to produce an electric current.

be hav ior (bẹ̄-hāv′yo̤r), the way an animal or a plant responds to things that happen in it or around it; the actions of a living thing.

Bet el geuse (bet′e̤l-jöz), the giant red star in Orion.

bind ing post (bīn′ding pōst), one of two screws or metal fasteners on a dry cell or other cell to which a wire is connected to complete an electrical circuit.

bird sanc tu a ry (sangk′ţū-ạ̄-ri), a place where birds can live and raise their young in safety.

car bon di ox ide (kär′bo̤n dī-ok′sīd), a gas that cannot be seen or smelled and is made of carbon and oxygen.

carbon rod, a rod of hard carbon in the center of a dry cell.

carbon tet ra chlor ide (tet-ra-chlō′rīd), a chemical that changes to a gas which is heavier than air.

car ti lage (kär′ti-lạ̄j), a firm, flexible material, not so brittle as bone, that forms parts of a skeleton. Gristle is cartilage.

cell, one of the small sections of which all plants and animals are made; part of an electric battery.

char ac ter is tic (kar′a̤k-te̤-ris′tik), a special feature of a material that makes it different from other materials.

charged, made capable of furnishing electricity again. Storage batteries are charged.

chem i cal change (kem′i-ka̤l chānj), a change in a material that makes a new or different material.

chlo rine (klō′rin or klō′rēn), a gas often used for killing germs in water.

cir cuit (sėr′kit), the path in which electricity travels.

com bus ti ble (ko̤m-bus′ti-bl), able to catch fire and burn.

com et (kom′et), a heavenly body, made up of gases and some solid particles, that usually has a head and a tail.

complete cir cuit (sėr′kit), an electrical connection in which one wire carries electrical current to an appliance, such as a toaster, etc., and another wire carries the current away.

con duc tor (ko̤n-duk′to̤r), a material through which heat, electricity, or sound can pass.

con ser va tion (kon-sėr-vā′sho̤n), preventing the waste of natural wealth (forests, coal, wild life, etc.) by careful use.

con stel la tion (kon-ste-lā′sho̤n), a group of stars.

con ta gious (ko̤n-tā′jus), spreading by touch. A contagious disease is one in which the germ can be passed directly from a sick person to another person or spread by touching objects handled by the sick person.

cor al (kor′a̤l), a tiny sea animal whose skeleton makes the hard red, pink, or white material that we call coral.

cul ti vate (kul′ti-vāt), keep the soil loose and free from weeds.

cul ti va tor (kul′ti-vā-to̤r), a machine that is used for loosening the soil and destroying weeds.

cy cad (sī′kad), a tree that looks somewhat like a palm tree.

de cay (dẹ̄-kā′), rot. A kind of chemical change brought about by bacteria and fungi.

di no saur (dī′nọ̄-sâr), one of a group of giant reptiles that lived millions of years ago.

dis solve (di-zolv′), change to a liquid form by mixing with a liquid.

dry cell, a device that makes electricity by chemical change in materials that are tightly sealed within a metal container.

ear-drum (ēr′drum), the thin skin stretched across the opening to the inner part of the ear.

ech o (ek′ō), the sending back of sound waves by a cliff or a hillside, so that shouted words are heard again as if from a distance.

e clipse (ẹ̄-klips′), passing from sight because light is cut off.

e lec tro mag net (ẹ̄-lek′trọ̄-mag′net), a piece of iron made into a magnet by an electric current in a wire wound around the iron.

el e ment (el′ẹ̄-me̤nt), the simplest material. An element cannot be taken apart or separated into other materials.

en er gy (en′ėr-ji), the power to work or act.

ep i dem ic (ep-i-dem′ik), a rapid spreading of a disease so that many people have it at the same time.

e ro sion (ẹ̄-rō′zho̤n), the wearing away of rocks and soil by the force of wind and water.

e vap o rate (ẹ̄-vap′ọ̄-rāt), change into a gas.

fer ti liz er (fėr′ti-lī-zėr), a substance that is added to the soil to make it richer in food materials for plants.

field-glass (fēld′glȧs), an instrument that makes distant objects appear larger. It has lenses for each eye.

filament (fil′a̤-me̤nt), the thread-like wires in an electric-light bulb that glow and give off light.

force (fōrs), a push or a pull that produces, changes, or stops motion, as the force of gravity, the force of electricity, etc.

fossil (fos′il), the preserved remains, print, or mold of a plant or an animal.

fuel, a material that burns to give heat or light.

fungus, plural **fungi** (fung′gus, fun′jī), a plant that does not make food for itself, such as mushrooms, molds, mildews.

fuse (fūz), a part of an electric circuit that will melt and break the circuit if the current gets dangerously large. This helps to protect us from fires that might be caused by short circuits.

Galileo (gal-i-lē′ō), a famous Italian scientist (1564-1642).

generator (jen′e̤-rā-to̤r), a machine for making powerful electric currents.

germ (jėrm), a simple plant or animal too small to be seen with the naked eye, that causes disease.

gravity (grav′i-ti), the force that pulls all things toward the earth.

habit, an act that a person has done so often that he finally comes to do it without first stopping to think and decide what to do.

harrow (har′ō), an implement used by farmers to break plowed soil into finer pieces.

Herschel (hėr′she̤l), an astronomer who discovered the planet Uranus (1738-1822).

hibernate (hī′bėr-nāt), spend the winter in sleep as bears and some other wild animals do.

infectious (in-fek′shus), able to be spread from one person to another. An infectious disease is one that is caused by germs.

instinct (in′stingkt), the natural actions of an animal. An act done by instinct is one that does not have to be learned.

insulated (in′s̮ụ̄-lā-ted) **wire,** a wire covered with a material through which electricity will not pass or will pass only slightly.

insulator (in′s̮ụ̄-lā-to̤r), a material through which heat or electricity will not pass or will pass only slightly.

iris (ī′ris), the colored part of the eye around the pupil.

irrigate (ir′i-gāt), supply land with water from canals or ditches.

Jupiter (jö′pi-tėr), the largest planet in the solar system.

key, the part of the telegraph system that completes and breaks the circuit.

kindling temperature (kind′ling tem′pėr-a̤-t̮ụ̄r), the temperature at which a material will burst into flame.

larva, plural **larvae** (lạ̈r′vä̤, lär′vē), an early form of an insect.

Leeuwenhoek (lā′ve̤n-hu̇k), a Dutch scientist who first saw tiny plants and animals under a microscope (1623-1723).

legume (leg′ūm), a plant belonging to the same group of plants as beans, peas, and clover.

lens (lenz), a piece of glass or similar material, shaped so that when light rays pass through it, they are either brought together or spread farther apart.

light year, the distance that light travels in one year. A light year is used to measure distances between stars.

magnet (mag′net), a stone or piece of iron or steel that attracts, or draws to it, bits of iron and steel.

magnifying-glass (mag′ni-fī-ing-glȧs), a glass that makes things look larger.

mammal (mam′a̤l), the name of a group of animals. Mammals feed their babies milk from their own bodies.

mammoth (mam′o̤th), an animal that lived millions of years ago. It was much like an elephant, but was larger, had longer tusks, and had a hairy coat.

Mars (märz), the planet nearest the earth.

Mer cu ry (mėr′kṳ̄-ri), the planet nearest the sun.

mi ca (mī′kä̤), a mineral that divides into thin, partly transparent layers. Mica does not conduct heat easily.

mi cro scope (mī′krọ̄-skōp), an instrument used to make very small things look larger, so that we can study them better.

mi grate (mī′grāt), move from one region to another. Many birds migrate to a warmer region in the fall.

min er al (min′e̤-ra̤l), a material, such as iron, calcium, etc., found in small quantities in food and soil and necessary for plant and animal growth. A material, such as iron, taken from the earth by digging or mining.

mold (mōld), a kind of fossil formed when a plant or animal was buried in mud, decayed, and left a hole the same shape as its body in the hardened mud.

moon, a body that travels around a planet.

nat u ral (nat̮′ṳ̄-ra̤l) **gas,** a gas found in the earth.

ne on (nē′on), a gas that glows with a red light when an electric current is passed through it. Neon is used for lighted signs on streets, in stores, etc.

Neptune (nep′tūn), a planet so far from the earth and the sun that it cannot be seen with the naked eye.

ni chrome (nī′krōm), a material made of nickel and chromium that conducts electricity very poorly.

non-con duc tor (non-ko̤n-duk′to̤r), a material through which heat, electricity, or sound will not pass or will pass only slightly.

nurs er y (nėr′sėr-i), a piece of ground or place where young plants are raised for transplanting.

or bit (ôr′bit), the path of one heavenly body around another, such as the path of the earth, or any planet, about the sun.

O ri on (ọ̄-rī′o̤n), a group of stars in the southern sky.

ox y gen (ok′si-jen), a colorless, odorless gas that makes up one-fifth of the air.

par af fin (par′a̤-fin), a white, tasteless material like wax, used for making candles and sealing jars.

par tial e clipse (pär′sha̤l ẹ̄-klips′), an eclipse that does not completely hide the sun or moon.

Pas teur (pȧs-tėr′), a famous French scientist (1822-1895), who proved that many diseases are caused by germs.

pas teur ize (pas′tėr-īz), heat to 144° Fahrenheit for about one-half hour to kill disease germs.

per i scope (per′i-skōp), an instrument that is made by arranging mirrors so that you can see around a corner or above the surface, if you are under water or in a ditch.

Pe tri dish (pā′trē), a small, shallow dish of thin glass, with a closely fitting cover. It is used for growing bacteria.

pet ri fied (pet′ri-fīd), turned into stone.

pe tro le um (pẹ̄-trō′lẹ̄-um), an oily, dark-colored liquid, found in the earth, from which gasoline, kerosene, etc., are made.

plan et (plan′et), a large heavenly body that moves around the sun.

plan e toid (plan′e-toid), a small planet.

plug, an electrical connecting device.

Plu to (plö′tō), the last planet to be discovered and the one farthest from the sun.

Po la ris (pọ̄-lā′ris), the North Star, which is at the end of the handle of the Little Dipper.

pole, either end of the earth's axis; one of the two places in a magnet where the force is strongest.

print, a mark made by a plant or an animal when it is pressed into mud. This becomes a fossil when the mud hardens into rock.

prism (prizm), a piece of transparent glass with three sides. When white light passes through a prism, it is separated into colors.

prun ing (prö′ning), cutting out some of the branches from trees or shrubs.

pupil, the center of the eye through which light passes.

quarantine (kwor′a̤n-tēn), keep a person, animal, or plant having an infectious disease away from others.

reed (rēd), a small piece of wood or metal that vibrates and makes sound in certain musical instruments, such as the saxophone, the clarinet, etc.

reflect (rẹ̄-flekt′), throw back sound, light, heat, etc.

reflecting telescope (rẹ̄-flek′ting tel′ẹ̄-skōp), a telescope in which the light from the star or other heavenly body strikes a mirror and is reflected through a lens to the eye.

reflection (rẹ̄-flek′sho̤n), an image.

reptile (rep′til or rep′tīl), a cold-blooded animal covered with scales or plates and having lungs for breathing.

Rigel (rī′je̤l), the bright bluish-white star in the constellation of Orion.

rotate (rō′tāt), change the crops planted in a given field so that the same crop is not grown year after year in the same field.

rotenone (rō′tẹ̄-nōn), a chemical that is useful as an insect poison.

saliva (sa̤-lī′vä̤), the liquid in the mouth that helps to dissolve food.

sanitary (san′i-tạ̄-ri), clean and free from germs.

Saturn (sat′ėrn), the large planet that has rings around it.

scientist (sī′e̤n-tist), a person who spends his life studying science and discovering things about the world.

sedimentary (sed-i-men′ta̤-ri) **rock,** a kind of rock made from sediment, or the material that settles to the bottom of a body of water.

serum (sē′rum), a liquid used to prevent or cure a disease. It is obtained from a person or animal whose blood has made the chemical that will fight the disease.

short circuit (sėr′kit), the path of an electric current when it takes a "short cut" back to the place where it started instead of passing through the place where it is needed for use.

Sir i us (sir′i-us), the brightest star in the sky.

sock et (sok′et), a hollow part used in an electrical circuit for holding the plug in place.

so lar (sō′lä̤r) **system,** the sun and the planets, planetoids, moons, and comets that travel around it.

sound, the result heard when a material vibrates or moves rapidly back and forth.

sound waves, a series of waves that travel in every direction from a vibrating body.

sour soil, soil that is acid.

spore (spōr), a single cell that can grow into a new plant. Ferns have spores.

stim u lus, plural **stim u li** (stim′ụ̄-lus, stim′ụ̄-lī), any one of the things that happen in or around a plant or animal; anything that causes a response in a living thing.

stor age bat ter y (stōr′ạ̄j bat′ėr-i), a set of two or more wet cells that can be charged with electricity.

struc ture (struk′ţṳ̄r), the parts of anything; the way in which the parts of a thing are put together.

switch (swich), a device used to turn electricity on and off, that is, to make or break an electrical circuit.

tel e scope (tel′ę̄-skōp), an instrument for making things that are far away look nearer.

total e clipse (ę̄-klips′), an eclipse that completely hides the sun or the moon.

trans form er (trans-fôr′mėr), a device for changing the strength of an electric current.

trans par ent (trans-pãr′e̤nt), clearly seen through. Clear glass is a transparent material.

trans plant (trans-plant′), take a plant from one place and plant it in another.

tri al-and-er ror (trī′a̤l-and-er′o̤r), a method of learning in which an animal tries many different things in order to solve a problem and accidentally finds one thing that works.

tung sten (tung′sten), a silver-colored metal used in making steel and for electric-light bulb filaments. Tungsten is a poor conductor of electricity.

u ni verse (ū′ni-vėrs), all the heavenly bodies and the vast space between and around them.

U ra nus (ū′ra̤-nus), the planet whose orbit lies between Neptune and Saturn.

vac ci nat ed (vak′si-nā-ted), protected from a disease by having been given a very mild case of the disease through vaccine inserted under the skin.

vac cine (vak′sēn), a material put into the body to protect it against serious disease by giving the body a very mild case of the same disease.

valve (valv), a movable part in a musical instrument that changes the length of the columns of air in order to make different sounds.

Ve nus (vē′nus), the most brilliant planet.

vi brat ing (vī′brā-ting), moving back and forth rapidly.

vo cal cords (vō′ka̤l kôrdz), membranes in the throat that vibrate when air strikes them and so make sounds.

wet cell, a device that makes electricity by chemical change in metal plates and a liquid with which they are covered.

xy lo phone (zī′lọ-fōn or zil′ọ-fōn), a musical instrument made of a row of wooden or metal bars, sounded by striking them with wooden hammers.

zinc (zingk) **cup,** the metal container of a dry cell.

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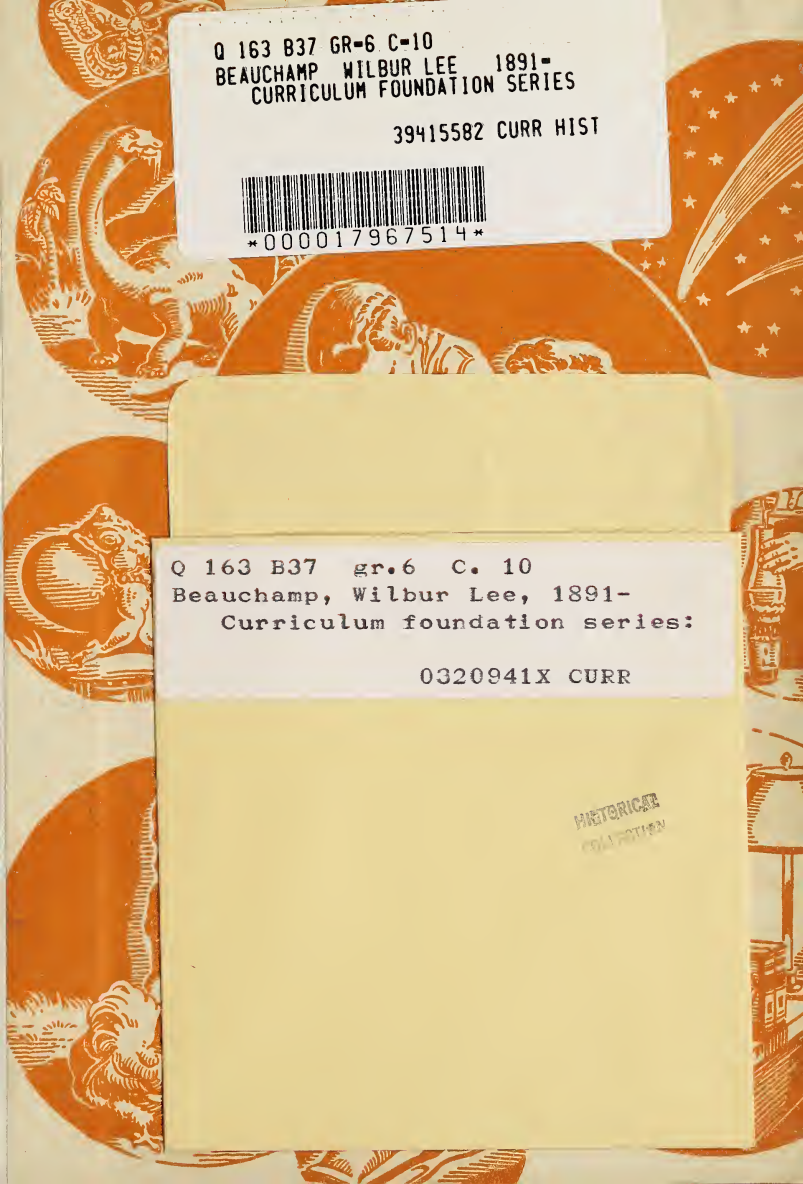

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